Trans-Lake Washington Project

AKART and Water Quality Studies for an SR 520 Replacement Floating Bridge

Prepared for

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ACRONYMS

ADT	average daily traffic
AKART	All Known, Available, and Reasonable Technology
BMP	best management practice
CADD	Computer-Aided Drafting and Design
cf	cubic feet
cfs	cubic feet per second
Cd	cadmium
Cu	copper
DCLU	Department of Construction and Land Use (Seattle)
EIS	environmental impact statement
ESA	Endangered Species Act
EMC	event mean concentration
EPA	Environmental Protection Agency
O/G	oil and grease
HM	Hydraulics Manual (WSDOT)
HOV	high-occupancy vehicle
HRM	Highway Runoff Manual (WSDOT)
HSPF	Hydrologic Simulation Program-Fortran
KCRTS	King County Runoff Time Series
KCSWDM	King County Surface Water Design Manual
LVM	Lacey V. Murrow Floating Bridge
NMFS	National Marine Fisheries Service
NPDES	National Pollution Discharge Elimination System
Pb	lead
SBUH	Santa Barbara Urban Hydrograph
SCS	Soil Conservation Service
SR	State Route
SWMMWW	Stormwater Management Manual for Western Washington (WSDOE)

ACRONYMS (Continued)

TSS	total suspended solids
ug/L	micrograms per liter
USFWS	U.S. Fish and Wildlife Service
WDFW	Washington Department of Fish and Wildlife
WSDOE	Washington State Department of Ecology
WSDOT	Washington State Department of Transportation
WWHM	Western Washington Hydrology Manual

1. INTRODUCTION

The existing Evergreen Point (SR 520) floating bridge across Lake Washington is proposed for replacement due to structural concerns and limited capacity. The bridge is located on Lake Washington between Seattle's west shoreline and Medina's east shoreline. Figure 1.1 shows the project location and surrounding features. This report summarizes the results of two studies regarding stormwater runoff from a proposed replacement floating bridge: a study of the water quality effects associated with stormwater discharges and a study of all known, available, and reasonable technology (AKART).

1.1 BACKGROUND AND OBJECTIVES

The Washington State Department of Transportation (WSDOT) is developing design alternatives and environmental documentation to replace the SR 520 floating bridge. Three floating bridge alternatives are proposed that vary by the number of lanes: four, six, or eight. In February 2002, WSDOT met with various federal and state resource agencies—Washington State Department of Ecology (WSDOE), United States Fish and Wildlife Service (USFW), Washington Department of Fish and Wildlife (WDFW), and National Marine Fisheries Service (NMFS)—to discuss design features, limitations, and water quality treatment options for an SR 520 replacement floating bridge. Following this meeting, WSDOE sent a memo to WSDOT specifying the analyses the department would require to come to a decision regarding stormwater treatment on the bridge. WSDOE requested that two detailed studies be prepared: 1) a water quality study, which examines potential water quality impacts of stormwater discharges from the replacement bridge to Lake Washington, and 2) an AKART study, which documents the feasibility of and justification for the proposed water quality protection measures.

The water quality and AKART studies have been conducted for the Washington State Department of Transportation (WSDOT) under Task 8.4.1 of Supplement 14 Work Order 7 for the State Route (SR) 520 Trans-Lake Washington Project. The project objectives for the AKART Study and Water Quality Study of the SR 520 Replacement Floating Bridge include the following:

- Develop and implement a project approach that meets WSDOT objectives for stormwater treatment and discharge options, and also meets with WSDOE approval;
- Develop an AKART Report that will provide an evaluation of stormwater treatment options, and define and document the design constraints and feasible stormwater engineering options for a replacement floating bridge;
- Develop a Water Quality Report that will provide an evaluation of the water quality of the stormwater runoff from a new bridge, and will document how the stormwater discharges are projected to meet state water quality standards; and

Insert Figure 1.1 Project Vicinity 8.5x11

- Communicate the results of the AKART and Water Quality studies to WSDOT, WSDOE, and other federal and state resource agencies. WSDOT would like to obtain concurrence from stakeholders regarding the chosen method for water quality treatment to facilitate the design of bridge elements affected by this decision.

The scope of work that was prepared for this project by CH2M HILL was based on a March 26, 2002, memorandum received from WSDOE outlining their expectations for the two reports. The sequence of tasks in the scope encourages stakeholder involvement at important points during study development. Copies of the WSDOE memorandum and final project team scope of work are included in Appendix A.

1.2 REPORT STRUCTURE

Section 2 describes the characteristics of floating bridges that influence stormwater runoff conditions and the design, construction, and maintenance of water quality treatment facilities. Section 3 reports the findings of the AKART study and Section 4 summarizes the results of the water quality study.

2. FLOATING BRIDGE AND STORMWATER CHARACTERIZATION

Stormwater drainage systems on Washington's existing floating bridges vary depending on the age of the structure and pontoon geometry. The following discussion presents a characterization of the proposed SR 520 replacement floating bridge and its stormwater runoff.

2.1 PHYSICAL AND STRUCTURAL CONSTRAINTS

Floating bridges present unique physical and design constraints due to their movement, geometry, maintenance requirements, and location in an aquatic environment. The physical and structural constraints associated with floating bridges across Lake Washington increase the technical difficulty of traditional approaches to onsite water quality treatment.

2.1.1 Movement

Floating bridges are subjected to one of the most severe bridge environments. The SR 520 replacement floating bridge will be designed to accommodate movements resulting from wind and wave actions, specifically wind speeds up to 92 mph, 4.6-feet vertical lake level fluctuations, wind-induced currents up to 3 feet per second, and seismic forces up to 75 percent of gravity loads. To accommodate the large pontoon deflections resulting from these loads and forces, the elevated structure will be designed with concrete and steel structures with open joints in the deck and barrier that allow it to flex.

2.1.2 Bridge Geometry

Because the roadway profile drops in grade onto the pontoons on the west end of the bridge and elevates in grade to leave the pontoons on the east end, a sag roadway profile is created. This profile is opposite of the one needed to convey stormwater off a bridge naturally. The floating portion of the replacement bridge will be over 7,000 feet long, making stormwater conveyance off the ends of the bridge difficult at best. At each end of the floating portion of the bridge, a transition span will allow the pontoons to rise and fall with lake level changes and twist and roll with wind and wave loading, while maintaining a smooth surface for vehicular traffic. The floating portion of the bridge must also allow for the wide range of vehicular loads on the structure; these loads increase the draft of the floating pontoons (i.e., the distance of the pontoons underwater). (Appendix B provides the Preliminary Bridge Layout Drawings.)

The roadway deck will be elevated above the pontoons to allow waves from moderate to small storms can break across the pontoon deck without splashing vehicles. This design eliminates solid barriers from the pontoon deck that impede the rapid drainage of stormwater. It was determined that the solid barriers on the original Hood Canal bridge contributed to the sinking of the west half of the bridge in 1979. The solid barriers retained large amounts of water on the deck which forced its way through hatches and increased loading on the bridge. Even though the elevated roadway will not be subjected to the same wave loading as the pontoon deck, it will need numerous large grated drains to allow rapid wave and rainwater drainage during storms.

2.2 FLOATING BRIDGE MAINTENANCE

Floating bridges require unique practices to meet their maintenance requirements. Most significantly, the proposed column-supported roadway deck for the bridge will allow a majority of maintenance operations to take place below the roadway without closing the bridge to traffic. This configuration is intended to minimize traffic disruptions and to reduce maintenance staff's exposure to traffic hazards. Maintenance of floating bridge systems includes monitoring and maintaining numerous elements such as cable anchors, ballast, pontoon cell interiors, and detection systems.

The Blue Ribbon Panel Report (1991), which documented the investigation of the sinking of the Lacey V. Murrow (LVM) floating bridge, states "WSDOT should make provisions for inspection and maintenance that exceed standard construction practices and reflect the floating nature of the bridges." The report also requires that WSDOT install a monitoring and piping system that allows detection and removal of water from flooded pontoon cells. In addition, the report states "the emphasis is placed on the water-tightness of the bridge and the reliability of electrical and mechanical systems."

As a result, the design of a stormwater drainage system must consider the bridge's water-tightness and electrical and mechanical systems when selecting a water quality treatment method. Bridge drainage features that allow staff to efficiently and safely maintain the bridge are important considerations and factors in evaluating options. Maintenance-friendly drainage systems will maximize the success of pollutant removal from a bridge's stormwater runoff.

In addition to the severe loading, the bridge will be subject to a highly corrosive environment due to its constant contact with lake water.

2.3 SPILL CONTROL AND STORMWATER SYSTEMS

Because SR 520 is a designated trucking route, trapping petroleum spills and other floating pollutants is a particular concern for protecting Lake Washington and its aquatic species. The proposed replacement bridge design creates separate enclosed spill containment lagoons with the use of the parallel roadway (or main) pontoons and cross pontoons (refer to Appendix B). These spill, or discharge, containment lagoons are designed to provide an area where any roadway spill of petroleum or floatable substances would be contained and allow for efficient cleanup.

Figure 2.1 provides a schematic plan view drawing of the discharge containment lagoon for each of the bridge alternatives. The proposed stormwater drainage system is designed to discharge all runoff flows into the lagoons between the pontoons. Two types of drainage systems are under consideration for the replacement bridge design, and these are both shown on Figure 2.1. One system would employ catch basins with vertical discharge pipes that terminate below the surface of the containment lagoons. The number and location of catch basins is shown schematically on

Insert Figure 2.1
Schematic Plan View of Stormwater System Configuration

Figure 2.1 and defined on the drawings in Appendix B. A different system would employ the use of vaults located on the cross pontoons that would each collect the runoff from the roadway above an entire main pontoon as well as a portion above the cross pontoon. The vaults would discharge into the ends of the containment lagoon, with two vaults discharging into each lagoon (Figure 2.1). The volume of stormwater collected and discharged into the lagoons is effectively the same with the two systems. Table 2.1 provides a summary of the stormwater discharge system configurations and dimension for both the catch basin and vault systems. This water quality study evaluated discharges from both systems for their effect in the lagoon and the adjacent lake.

2.4 STORMWATER QUALITY AND POLLUTANT LOADS

Stormwater quality data from highways has been the subject of various research studies with little data available for bridges specifically (FHWA, 1996; CH2M HILL, 2001). These studies acknowledge that highway pollutant loadings are site-specific and are influenced by factors such as impervious surface, traffic, precipitation characteristics, and amount of offsite "run-on" contribution. Because site-specific stormwater quality data from the existing SR 520 bridge is unavailable, pollutant loads for this study were estimated from the accepted pollutant loading methodology described in FHWA (1996),WSDOT (1997), and CH2M HILL (2001), and developed by Driscoll/Federal Highway Administration. An extensive and recent stormwater runoff database (Kayhanian, 2002) was used with this methodology to generate equations estimating annual pollutant loads based on percent impervious area, precipitation, average daily traffic, and location. This recent stormwater runoff database was developed from samples taken at 31 highway runoff sites during 192 storm events throughout California in 2000 and 2001. The 31 highway sites were monitored as part of the Caltrans Statewide Stormwater Runoff Characterization Program (Kayhanian, 2002). For SR 520, pollutant loadings for TSS and metals were assumed to reflect the event mean concentrations (EMC) in the Caltrans database. This assumption was judged reasonable based on the following:

- The Kayhanian/Caltrans study reflects current monitoring results on west coast highways.
- The floating portion bridge is located an appreciable distance from land with zero "run-on" contribution.
- Pollutant loads generated from the high-occupancy-vehicle/bus-rapid-transit lanes are expected to be lower than general purpose lanes.

Results in Table 2.2 show estimates of pollutant loading by highway pollutant constituents per catch basin, vault, lane mile, and total bridge deck. The stormwater event mean concentration values for cadmium, copper, lead, and zinc have been used to represent the average stormwater discharge concentrations for the AKART and water quality studies. These are considered to be

Table 2.1
Stormwater Discharge System Configurations and Dimensions for the Bridge Alternatives

Stormwater Alternative	Bridge Lane Alternative	No. Catch Basins or Vaults per Bridge Section[1]	Discharge Pipe Configuration		Dimensions of Containment Lagoon per Pontoon Section (feet)			Volume (ft^3)	Lagoon Depth & Volume
			No. Discharge Pipes from each Pontoon	Assumed Pipe Spacing (ft)[2]	Length	Width	Draft (Depth)[3]		
I. Pontoons with Catch Basins	4	6	3	180	360	3.1	12	13,591	Minimum
		6	3	180	360	3.1	17	19,254	Average
		6	3	180	360	3.1	22	24,916	Maximum
	6	8	4	120	360	6.1	12	26,460	Minimum
		8	4	120	360	6.1	17	37,485	Average
		8	4	120	360	6.1	22	48,510	Maximum
	8	14	7	60	360	18.1	12	78,300	Minimum
		14	7	60	360	18.1	17	110,925	Average
		14	7	60	360	18.1	22	143,550	Maximum
II. Pontoons with Vault System	4	2	1	420	360	3.1	12	13,591	Minimum
		2	1	420	360	3.1	17	19,254	Average
		2	1	420	360	3.1	22	24,916	Maximum
	6	2	1	420	360	6.1	12	26,460	Minimum
		2	1	420	360	6.1	17	37,485	Average
		2	1	420	360	6.1	22	48,510	Maximum
	8	2	1	420	360	18.1	12	78,300	Minimum
		2	1	420	360	18.1	17	110,925	Average
		2	1	420	360	18.1	22	143,550	Maximum

Notes:

[1] Each floating bridge section consists of two main pontoons (with road sections above) in parallel, with a containment lagoon between and cross pontoons at each ends.

[2] Spacings between stormwater drainage pipes are based on catch basin spacings developed by WSDOT engineers for the various lane alternatives (Engineering Drawings from Preliminary Drainage Layout, SR 520-Lake Washington Floating Bridge, Sheet 1).

[3] The pontoon draft (depth below surface) will vary from 12 feet (minimum) in the middle to 22 feet at the ends of the bridge, based on information from WSDOT engineers.

Table 2.2
Estimate of Pollutant Loading

		Pollutants						
	Units	**TSS**	**Oil/Grease**	**Cadmium[c]**	**Copper**	**Lead**	**Zinc**	**Parameters/Assumptions[c, d]**
Average Event Mean Concentration[a] (EMC), Cm	mg/L	94.4	9.47[b]	0.005	0.022	0.022	0.130	Eq 8: Cm = Cmed * (1+CV^2)^0.5
Runoff Coefficient, RV		0.8	0.8	0.8	0.8	0.8	0.8	RV = 0.007 * % Impervious Area + 0.10, % Imp Area = 100%
Rainfall Volume for the Mean Storm Event, Hms	mm	11.7	11.7	11.7	11.7	11.7	11.7	Table 13, p. 55, Seattle
Area, A	ha/catch basin	0.067	0.067	0.067	0.067	0.067	0.067	Assume 6-Lane Alt., 60 ft wide, 120 ft between catch basin
	ha/vault	0.234	0.234	0.234	0.234	0.234	0.234	Assume 6-Lane Alt., 60 ft wide, 420 ft between vaults
	ha/lane-mile	0.59	0.59	0.59	0.59	0.59	0.59	Assume 12-foot lane width, 1 mile length of bridge
	ha for 6-lane total bridge	7.95	7.95	7.95	7.95	7.95	7.95	Assume 6-Lane Alt., 120 ft total width, 7,132 ft length
Volume of Runoff for Mean Storm Event, Vms	m^3/catch basin	6.3	6.3	6.3	6.3	6.3	6.3	Eq 7: Vms = RV * Hms * A *10
	m^3/vault	21.9	21.9	21.9	21.9	21.9	21.9	
	m^3/lane-mile	55.2	55.2	55.2	55.2	55.2	55.2	
	m^3 for 6-lane total bridge	744.1	744.1	744.1	744.1	744.1	744.1	
Mean Event Mass Load, Lm	kg/event/catch basin	0.592	0.059	0.000	0	0	0.001	Eq 9: Lm = Cm * Vms/1000
	kg/event/vault	2.068	0.207	0.000	0	0	0.003	
	kg/event/lane-mile	5.213	0.523	0.000	0.001	0.001	0.007	
	kg/event for 6-lane total bridge	70.245	7.047	0.004	0.017	0.016	0.097	

Table 2.2
Estimate of Pollutant Loading

		Pollutants						
	Units	TSS	Oil/Grease	Cadmium[c]	Copper	Lead	Zinc	Parameters/Assumptions[c, d]
No. of Storms Per Year, Ns	Events/yr	86.7	86.7	86.7	86.7	86.7	86.7	Ns = 24 * 365/Ts where Ts = interval mean = 101, Table 13, p. 55, Seattle
Annual Mass Loading, La (Metric Units)	kg/yr/catch basin	51.35	5.15	0.00	0.01	0.01	0.07	Eq 10: La = Lm *Ns
	kg/yr/vault	179.33	17.99	0.01	0.04	0.04	0.25	
	kg/yr/lane-mile	452.15	45.36	0.02	0.11	0.10	0.62	
	kg/yr for total bridge deck	6,092.53	611.19	0.32	1.44	1.41	8.38	
Annual Mass Loading, La (English Units)	lb/yr/catch basin	114.10	11.45	0.01	0.03	0.03	0.16	1 lb force = 4.45 N = 1 kg * 9.8 m/s^2
	lb/yr/vault	398.51	39.98	0.02	0.09	0.09	0.55	
	lb/yr/lane-mile	1,004.78	100.80	0.05	0.24	0.23	1.38	
	lb/yr for total bridge deck	13,539	1,358	0.72	3.20	3.14	18.62	

Notes:

[a] Source: Kayhanian, M., L. Hollingsworth, M. Spongberg, L. Regenmorter, and K. Tsay. January 2002. Characteristics of Stormwater Runoff from Caltrans Facilities. Transportation Research Board, Annual Conference, Washington, D.C. Table 3.

[b] Source: FHWA (Federal Highway Administration). March 1985. Effects of Highway Runoff on Receiving Waters, Vol. III, Resource Document for Environmental Assessments. Publication No. FHWA/RD-84/064. Table 1. Summary of highway runoff quality data for six monitoring sites and typical urban runoff quality based on data from 28 cities: Average Pollutant Concentration.

[c] EMC from Kayhanian, et. al. (2002) is 0.0007 mg/L. Used maximum value in range.

[d] Source: Federal Highway Administration. June 1996. Evaluation and Management of Highway Runoff Water Quality. Pub. No. FHWA-PD-96-032. Federal Highway Administration Method for Estimating Pollutant Loading, Section 3.2.3, p. 52.

Abbreviations:

ha = hectare
m^3 = cubic meter
kg = kilograms
lb = pound
mg/L = milligrams per liter
mm = millimeters
yr = year

reasonable and conservative metals estimates. Earlier stormwater runoff data such as the FHWA study (Driscoll, 1990) were no longer applicable because many values were developed when leaded gasoline was still in use, and automobile tires and emissions have changed since that time.

2.5 HYDROLOGY

The Seattle area, where the project is located, is characterized by approximately 36 inches of annual rainfall. Consistent with the Stormwater Management Manual for Western Washington (SWMMWW), the design treatment storm for the project is defined as the volume associated with 91 percent of the total runoff volume over the period of the historical record. The design treatment storm is also referred to as the "water quality treatment storm."

Flow rates were estimated in accordance with the SWMMWW. Based on the SWMMWW, the water quality design storm flow is computed by applying a ratio to the 2-year flow, which is determined by use of a continuous simulation flow model with a 15-minute time step. Because the Western Washington Hydrology Model (WWHM v1.25e) does not incorporate the algorithm for water quality flow computation and the 2-year flow is computed using a 1-hour time step, a greater accuracy was assumed for this report by using the 2-year flow from the King County Runoff Time Series (KCRTS) Model with its 15-minute time step. The water quality design storm flow was estimated by applying the SWMMWW ratio (Table 4-1 in the SWMMWW Manual) to the KCRTS estimated 2-year flow, assuming 100 percent impervious area.

For estimating stormwater quality design volumes (6-month, 24-hour storm), the Soil Conservation Service (SCS) Curve Number method was used (72 percent of the 2-year volume) with the following parameters:

- 100 percent impervious (Curve Number = 98)
- 2-year depth = 1.8 inches

For the 6-lane alternative, the estimated treatment flow for each catch basin is 0.034 cubic feet per second (cfs) and for each vault (one direction) it is 0.119 cfs. The estimated treatment volume for each vault (one direction) is 2,269 cubic feet (cf). See Appendix C for calculations.

2.6 HYDRAULICS

Flow characteristics on the floating bridge present a few constraints that should be acknowledged. Precipitation initially sheet flows from the roadway surface to the inside gutter. Along the transition spans, flow will be conveyed down the gutter, into catch basins, and conveyed in storm drains discharging eventually to the first spill lagoon. Between transition spans, the roadway profile is essentially level and requires consideration of weir flow into the grates (i.e., ponding at the grate inlets). Larger, depressed inlet grates with closer spacing to maximize efficient drainage of the inside shoulders will be used. Estimated spacing is indicated on initial layouts (Appendix B). Vertical bridge movement results in flow directions that may reverse along the gutterline. The flat hydraulic profile along the gutterline also results in higher than average debris/sediment deposition on the shoulder prior to conveyance into the catch basins.

3. AKART STUDY

This section reviews the initial screening process used to identify the known and available technologies compared in this section, and describes the factors used to compare alternative technologies and the results of the comparison.

3.1 IDENTIFICATION AND SCREENING OF KNOWN AND AVAILABLE TECHNOLOGIES

This section describes the process used to identify and screen known and available technologies.

3.1.1 Literature Search

A literature search was conducted to identify known highway stormwater treatment technologies and sources of information on highway water quality. The information sources used in the search was from a broad base. A draft list of information sources was reviewed by stakeholders prior to further screening. The information sources included Internet journal search, Dialogue databases, Transportation Research Service, several transportation agencies (WSDOT, MDOT, WISDOT, ODOT, Caltrans), EPA, and WSDOE. Vendors and research authors were also consulted for additional information. See Appendix D.

3.1.2 Screening Process

Following the literature search, the known treatment technologies went through an initial screening. The screening identified and eliminated technologies considered technically infeasible on a floating bridge (based on information gathered to date and common knowledge of the technologies). This screening process was conducted by an interdisciplinary team of design and environmental staff. In summary, the issues of safety, maintenance, engineering, environment and cost were addressed in a series of questions. The responses were summarized in a memo and matrix. The screening criteria and a detailed description of the screening methodology can be found in the Screening Memo contained in Appendix D.

3.1.3 Description of Screening Results

The technology screening resulted in reducing the initial 15 categories of technology to 4 categories for further evaluation in this study. The four technology categories are as follows:

- Media filtration—vaults
- Catch basin media filtration
- High-efficiency sweeping
- Modified catch basin sweeping/cleaning

3.1.3.1 Media Filtration—Vaults

Slow media filtration technology consists of conveying untreated stormwater through media beds, or canisters of enclosed media. Different types of media target specific pollutants. For example, sand and pearlite target finer sediments, while peat and zeolite target metal removal. Because media filtration is generally poor at trapping large particles and oil and grease (O/G), it requires pre-treatment of these pollutants. Two configurations of media filtration are possible:

- Configuration 1: A horizontal media bed is installed in enclosed vaults on the pontoon deck. Stormwater filtration moves in a vertical direction by gravity and permeability of the media.

- Configuration 2: Media vaults with cartridges are another variation of media filtration. This consists of installing pre-engineered Stormfilter™ vaults on the pontoon deck. Flows are treated in each cartridge when a plastic float is raised, priming a siphon, and then drawing stormwater through the cartridges**.** Flows are controlled with small diameter orifice plates in the outlet piping, and discharge through the vault floor in 3- to 4-inch-diameter pipe to the discharge location.

Both configurations would require media vaults to be placed below the bridge deck on cross pontoons spaced every 420 feet.

3.1.3.2 Catch Basin Media Filtration

This alternative consists of media filtration placed inside individual catch basins on the bridge. Sediments are deposited within the media, which is replaced when saturated/plugged. Three configurations of catch basin filtration are possible:

- Configuration 1: Units with disposable filter/absorbent media pillows

- Configuration 2: Units with replaceable filter bags

- Configuration 3: Units with replaceable media cartridges

The first two configurations are commonly known as "catch basin inserts," and operate on the principle of gravity filtration of untreated flows through media pillows and geotextile-type fabric, respectively. Configuration 3 involves the siphoning of untreated flows through a submerged media cartridge and small-diameter pipe in each catch basin (similar to Configuration 2 of vault filtration.) These media cartridges have treatment flow limits. When the flow limits are reached, or the media are plugged, flows bypass the cartridges.

3.1.3.3 High-Efficiency Sweeping

An "emerging technology" in the SWMMWW, this alternative uses "new generation" sweeping equipment to prevent pollutants from entering the drainage systems and receiving waters. The technology consists of high-pressure air circulation and vacuuming of pollutants from the bridge road surface into a sweeping vehicle. Pollutants are collected in the sweeping vehicle and driven off the bridge. A bridge deck sweeping program would be established; pollutants would be swept from the roadway and shoulders on a scheduled basis correlated to predicted removal rates.

3.1.3.4 Modified Catch Basin Sweeping/Cleaning

This technology category consists of combining larger than standard catch basin drainage structures (sized for increased sediment trapping capability) with a scheduled cleaning of trapped pollutants. Larger than standard sumps would provide increased residence time for sediments to collect prior to removal. In addition, oil/grease trapping could be provided with submerged outlets. (Schematics of the modified catch basins are presented in Appendix F.)

3.2 EVALUATION OF SCREENED ALTERNATIVES

The four technology categories were examined for possible stand alone or combination treatment alternatives appropriate for the floating bridge. The following four combination alternatives were developed:

- Alternative 1: Media filtration vaults with conventional sweeping
- Alternative 2: Catch basin filtration with conventional sweeping
- Alternative 3: Modified catch basins/cleaning with conventional sweeping
- Alternative 4: High-efficiency sweeping and modified catch basin/cleaning

Each alternative was developed based on the premise that at least two technologies would be employed for pollutant removal. (Note that conventional sweeping, although not identified as a BMP, is also assumed for Alternatives 1, 2 and 3. This is an existing strategy on WSDOT's floating bridges to minimize BMP cleaning frequency.

3.2.1 Discussion of Alternatives

This section describes each treatment alternative's technical feasibility, estimated effectiveness, and cost. Third party research/evaluations were used to compare effectiveness objectively. The pollutant removal effectiveness of individual technologies were added together to achieve a composite or total effectiveness value. The computed effectiveness of the technologies should only be used for purposes of comparison. Results in Table 2.2 show estimates of pollutant loading by highway pollutant constituents per catch basin, vault, lane mile, and total bridge deck.

3.2.1.1 Alternative 1: Media Filtration Vaults

Two configurations are discussed for Alternative 1. Both configurations would incorporate conventional street sweeping and modified catch basins as pretreatment.

Technical Feasibility *Configuration 1* Horizontal media vaults would be located on the lower cross pontoon deck and discharge to the spill lagoons at each end of the pontoon. Vaults would be placed on every cross pontoon (420-foot spacing) to allow for adequate conveyance of stormwater from the bridge deck. Due to bridge lateral movement between eastbound and westbound bridge structures, two vault systems would be at each cross pontoon (two vaults per cross pontoon). Estimated vault size is approximately 20-ft x 20-ft x 3-ft of sand media, with over 25 tons of water weight when full (based on the SWMMWW Sand Filter Simple Sizing Method). As documented in the Screening Memo (see Appendix D), storing large quantities of water on the bridge would create irregular dynamic responses, risking the structural integrity of the bridge.

A peat media bed footprint would be approximately 10-ft x 5-ft based on permeability of 2.5 gallons per minute (gpm) per square foot (sf) (Snohomish County Public Works, 1999). The author of this report cited several hydraulic capacity problems in the systems studied due to biological growth fouling the piping system (Bill Leif, personal conversation). Frequent maintenance and monitoring will be required (once every two to three months for the first year). In addition, movement of media beds would be expected on the bridge, with possible bypassing of flows and premature plugging. Based on these technical limitations, Configuration 1 (horizontal media vaults) is considered infeasible for the replacement floating bridge.

Configuration 2 Similar to media beds, vaults containing media cartridges would be located on the lower cross pontoon decks, and would discharge to the spill lagoons at each end of the pontoons. Based on the Draft Conditional Short-Term Use Designation (CSTUD) for the Stormfilter (WSDOE, 2002), it is estimated that two vaults would be located at each cross pontoon (one for eastbound drainage, the other for westbound drainage). These pre-engineered units are manufactured by only one company, Stormwater Management, Inc. As a result, there is a sole source for cartridges, media, and associated hardware. An estimated 12 pearlite/zeolite cartridge filters would be needed for each of the two 6-ft x 12-ft vaults located on each cross pontoon.

Vaults would have to be covered to protect media from wave action. Maintenance of the media vaults would require accessing them from the edge of the bridge by boat and barge. Deposited sediment in vault beds and cartridges would require removal by hand and crane respectively. Peat beds would require hand removal and replacement due to size and difficult access. Barge transport of material to/from a truck on land would be needed. Biological fouling of moving parts and piping system were observed in a Stormfilter system in Snohomish County where systems required constant inspection and maintenance (Bill Leif, personal conversation). Primarily due to its moving parts, reliability of the system was generally low. Caltrans (2002) also cited maintenance concerns where mosquito larvae formation caused regular maintenance of Stormfilter systems.

Estimated Effectiveness This alternative combines the effectiveness of conventional sweeping, modified catch basins, and media filtration vaults. Conventional sweeping will be necessary to remove roadside debris and keep the cleaning maintenance of catch basins to a minimum. Modified catch basins are necessary as a pretreatment to media filtration for solids settlement. The composite estimated effectiveness of the treatments used in series (conventional sweeping, catch basins and media filtration) is calculated in Table E-1 (Appendix E).

The estimated effectiveness of media filtration was the subject of several studies including Snohomish County (1999) and Caltrans (2002). For total suspended solids (TSS), assumed removal efficiencies ranged from 81 percent to 99 percent. For O/G, removal efficiencies ranged from 46 percent to 90 percent. Total cadmium, copper, lead, and zinc respectively have wide effectiveness ratios from 45 percent to 90 percente, 44 percent to 98 percent, 60 percent to 97 percent, and 39 percent to 97 percent (see Table E-1 in Appendix E). Caltrans (2002) reported dissolved copper, lead, and zinc efficiencies as 15, 15, and 16 percent, respectively. Differences in influent concentrations and particulate make-up primarily affect this large range of removal. Tobiason et.al. in a laboratory zinc removal test using leaf compost (CFS) media, zeolite/pearlite mix, and a polyamine sponge, found that zinc removal was inconsistent and decreased with increasing influent concentration for the zeolite/pearlite and CFS media.

Estimated Cost The 20-year present worth cost of Alternative 1 is estimated between $5,852,000 to $6,810,000. The cost includes the capital investment cost of a maintenance barge and the operation and maintenance cost of using the barge.

3.2.1.2 Alternative 2: Catch Basin Filtration

Technical Feasibility Catch basin inserts (Configurations 1 and 2) are predominantly manufactured for smaller, standard catch basins (i.e. WSDOT Type 1) instead of the larger grate inlet drainage structures proposed for the bridge. If catch basin inserts are placed inside the larger bridge inlets, non-standard reducing collars are needed to concentrate flow into the smaller filters. This concentration of flow down the collar and along the inside rim of the insert could cause preferential flow patterns and a concentration of pollutants along the perimeter of the insert. The Santa Monica Cities Consortium (1998) found that density in pillows was an important consideration. As sorbents become coated with oil and grease, flow will tend to channelize and create areas of unsaturated sorbent. This action, coupled with differential flow patterns created by use of non-standard reducing collars, could lead to increased maintenance requirements and have not been documented in the literature to assure pollutant removal performance. Maintenance is highly variable and they cannot be operated unattended. Continual monitoring to prevent plugging and flooding is expected. Caltrans (2002) further observed that timing of maintenance is critical, right before and during storm events to keep them clean, since available storage volumes are low. Based on these technical limitations, Configurations 1and 2 are considered infeasible on the bridge.

Catch basin media filtration with cartridges (Configuration 3) is further evaluated. These units are manufactured by only one company, Stormwater Management, Inc., and hence require dependence on a single source for cartridges, media, and associated hardware. Units are typically sold in a two treatment system—a pre-settling catch basin chamber connected to a separate chamber containing the cartridge filter. A modified catch basin, as described in Section 3.1.3.4, would be used as the pre-settling chamber. Since ponding on the bridge shoulder near the gutter is characteristic of the floating bridge drainage system, large grate inlets are required to facilitate the weir flow hydraulics of the system. Standard catch basin media filters would require a custom design to allow for the large grate inlet. Based on vendor discussions, a chamber downstream of a bridge catch basin would need three cartridge filters to handle flows and estimated pollutant loads. The use of filter cartridge raises maintenance problems similar to those cited above for Stormfilter media vault cartridges, including biological fouling of moving parts and piping system observed by Bill Leif (personal conversation) of the Snohomish Surface Water Management Division. Reliability of the system is unpredictable, primarily due to its moving parts. Caltrans (2002) also observed increased vector habitat in the stagnant water of the systems.

Approximately 120 chambers would need to be maintained. Maintenance would require an estimated 600 hours per year for replacements and inspections. Maintenance workers would have to work within the 10-foot, inside shoulder adjacent to traffic.

Estimated Effectiveness

Similar to Alternative 1, this alternative combines the effectiveness of conventional sweeping, modified catch basins, and media filtration vaults. Conventional sweeping will be necessary to remove roadside debris and to keep the cleaning of catch basins to a minimum. Modified catch basins are necessary as a pretreatment to media filtration for solids settlement. The composite estimated effectiveness of these treatments used in series (conventional sweeping, modified catch basins, and media filtration vaults) is calculated in Table E-1 (Appendix E).

Catch basin inserts primarily target hydrocarbons in oil and grease. Configurations 1 and 2 have been specified as BMPs in recent effectiveness studies (Caltrans, King County, and Snohomish County). Results from these studies conclude that they are only effective for larger particles of TSS, are not effective for metals, are prone to plugging due to low storage, and do not function unattended. In addition, the SWMMWW specifies that these units be used for oil control measures, but not for sediment or metal control.

The composite estimated effectiveness of Configuration 3 is 81 percent to 99 percent for TSS, 46 percent to 90 percent for O/G, 45 percent to 90 percent for cadmium, 44 percent to 98 percent for copper, 60 percent to 97 percent for lead, and 39 percent to 97 percent for zinc (see Appendix E).

Estimated Cost Implementation of Alternative 2 is estimated with a 20-year present worth cost between $3,346,000 to $3,727,000.

3.2.1.3 Alternative 3: Modified Catch Basins/Cleaning

Technical Feasibility Because modified catch basins/cleaning would involve variations from conventional drainage structures, it would not require a new treatment technology applied to the bridge. Pollutants are deposited and collected in the catch basin sumps. Conventional sweeping is assumed as part of this BMP to reduce shoulder deposition and collect larger debris.

The catch basins would be cleaned using conventional bridge cleaning equipment (Vactor truck).

Estimated Effectiveness This alternative combines the effectiveness of using a conventional sweeper to remove roadside debris in series with modified catch basins. The composite removal efficiencies for the Alternative 3 treatments used in series are shown in Table E-1 (Appendix E).

Catch basin effectiveness studies in the literature have been modest to date. However, the technology has largely remained consistent over the years. The EPA (1977) documented the effectiveness of catch basins as a function of sump size and cleaning frequency. From an annual to a bi-annual cleaning frequency, estimated total solids removed were 39 percent to 75 percent. Leif (1998) found that the removal efficiency for a 19-inch catch basin sump with 25 gpm was 82 percent to 98 percent for medium sand. The water quality design flow for catch basins on the floating bridge is 21gpm. Pitt (1985) concluded that catch basins can capture sediments up to approximately 60 percent of the sump volume. Modified catch basins on the bridge are assumed as 32 cf total volume (2-ft wide x 4-ft long x 4-ft deep). Composite estimated effectiveness of Alternative 3 treatment measures is 49 percent to 93 percent for TSS. This accounts for the variability in efficiency between bi-annual and annual cleaning frequency.

Estimated efficiencies for heavy metal removal was calculated by using a mass balance approach where only the particulate fraction of total metals was used to estimate the pollutant removal load. An FHWA (1990) document indicates that total copper and total zinc are typically found to be 60-percent particulate and 40-percent soluble in composition. Total lead is typically found in urban runoff as 90-percent particulate and 10-percent soluble. These estimates are similar to findings from Caltrans (2002) that observed the soluble fraction of lead, copper, and zinc to be 51 percent, 15 percent, and 46 percent, respectively. The soluble fraction of cadmium was observed to be 57 percent of total cadmium. The more conservative Caltrans study was used to estimate the percentage of particulate metal in estimating the removal efficiency of modified catch basins (43-percent particulate cadmium, 49-percent particulate copper, 85-percent particulate lead, and 54-percent particulate zinc). This methodology employing an estimate of the particulate fraction of metals was also used to calculate conventional sweeping efficiencies (see Table E-1).

The composite estimated pollutant removal effectiveness of Alternative 3 using modified catch basin/cleaning is 49 percent to 93 percent for TSS, 25 percent to 71 percent for oil and grease, 23 percent to 53 percent for cadmium, 25 percent to 59 percent for copper, 43 percent to 86 percent for lead, and 28 percent to 64 percent for zinc (see Table E-1).

Estimated Cost Implementation of Alternative 3 is estimated with a 20-year present worth cost between $1,256,000 to $1,516,000.

3.2.1.4 Alternative 4: High-Efficiency Sweeping and Modified Catch Basin/Cleaning

Technical Feasibility The existing floating bridges are currently swept with mechanical sweepers as a means to reduce the amount of pollutants entering the drainage systems and receiving waters. No problems have been identified in their ability to perform and operate on a floating bridge. This alternative would require the procurement and maintenance of a new sweeping vehicle, staff training, and a specified sweeping schedule to meet target removals. This alternative rates high in technical feasibility for reasons of maintenance, safety, non-proprietary nature, and functionality on the bridge. This alternative also minimizes maintenance staff exposure to traffic on the bridge. Some issues of concern relate to slow sweeper speeds and driver comfort, but these issues may be addressed in future sweeper models.

Estimated Effectiveness Several studies on newer "high-efficiency" sweeper technology (Sutherland, 1998) indicate their effectiveness is comparable to treatment BMPs (up to 77 percent removal), and significantly more effective than older mechanical sweeping technology in earlier research (EPA,1983). Effectiveness primarily depends on sweeping frequency prior to conveyance of pollutants off the roadway. The most relevant study to highways (Wisconsin Department of Transportation, 2002) examined sweeper effectiveness on an interstate highway in Milwaukie, with a wide range of removals. The more definitive and conservative effectiveness (Sutherland and Jelen, 1997) were assumed for this AKART study.

The composite estimated effectiveness of Alternative 4 using high-efficiency sweeping with modified catch basin/cleaning is 70 percent to 94 percent for TSS, 55 percent to 72 percent for cadmium, 47 percent to 70 percent for copper, 64 percent to 85 percent for lead, and 45 percent to 70 percent for zinc (see Table E-1 in Appendix E).

Estimated Cost The 20-year present worth cost of Alternative 4 is between $1,072,000 to $2,169,000. The range includes the cost of a regenerative sweeper (low end) to a vacuum sweeper (high end).

3.2.2 Ranking of Alternatives

This section summarizes and ranks the reasonableness of each alternatives as defined by technical feasibility, effectiveness, and estimated cost. With this information, an AKART determination can be made.

3.2.2.1 Technical Feasibility

A technically feasible alternative meets the following criteria for siting, operation and maintenance:

- The alternative should operate and perform when subjected to the SR 520 floating bridge environment, where movement during storms and normal bridge vibrations does not decrease the performance of the alternative.

- The alternative should not require storage of significant volumes of water on the bridge, compromising its structural integrity.

- Maintenance workers should not be exposed to undue safety risks.

- The alternative should not create water ponding on the roadway surface, leading to undue vehicular and pedestrian safety risks.

- The alternative should be consistent with the conclusions of the Blue Ribbon Panel report.

- The alternative should operate passively and unattended by WSDOT personnel.

- The long-term maintenance requirements and costs for the alternative must be known.

Table 3.1 identifies the technical feasibility of each alternative evaluated. Alternatives 1 and 2 (media filtration in vaults and catch basin filtration) are characterized as possessing a low technical feasibility due to low reliability and high maintenance requirements to assure proper functioning in a dangerous environment.

A higher degree of technical feasibility is associated with Alternatives 3 and 4 (modified catch basin cleaning and high-efficiency sweeping) primarily due to their functionality on the bridge, maintenance requirements, and safety.

Table 3.1
Comparison of Alternatives

Technical Feasibility Parameters	Alternative 1	Alternative 2	Alternative 3	Alternative 4
	Media Filtration Vaults	**Catch Basin Filtration**	**Modified Catch Basin/Cleaning**	**High-Efficiency Sweeping and Modified Catch Basin/Cleaning**
	Configuration 2 Media Filtration Cartridge	**Configuration 3 Replaceable Media Cartridges**		
Technical Feasibility				
TSS Removal	Medium	Medium	Low	Medium
Metals Removal	Medium	Medium	Low	Medium
Commercially Available With Long-Term Availability	Medium	Medium	High	High
Installation or Its Parts Non-Proprietary	Low	Low	High	Medium
Function in the Bridge Environment	Medium	Medium	High	High
Reliability	Low	Low	High	Medium
Accessible and Reasonable to Maintain	Low	Low	Medium	High
Acceptable Risk of Flooding Roadway	High	Medium	High	High
Overall Technical Feasibility Rating	***Low***	***Low***	***Medium***	***High***
Measures of Cost				
Overall Cost	High	Medium	Low	Medium
Cost Effectiveness	Low	Low	Low	High

3.2.2.2 Cost Effectiveness

The estimated pollutant removal of each alternative is summarized in Table 3.2. The 20-year present costs are summarized in Table 3.3. The cost assumptions used to prepare the estimates are provided in Appendix E (Table E-3). The cost effectiveness of the treatment alternatives can be expressed by plotting the estimated annual pollutant load discharged to Lake Washington versus the estimated treatment cost. These are shown for each pollutant of concern (TSS, O/G, copper, lead, and zinc) in Figures 3.1 through 3.6.

The cost-effective analysis illustrates the principal of “diminishing returns” for most pollutants when examining the alternative that appears most effective (i.e., media filtration).

3.2.2.3 Comparison of Alternatives

A comparison of alternatives based on effectiveness, technical feasibility, cost, and cost effectiveness appears in Table 3.1.

Alternative 1 (media filtration vaults with modified catch basin/cleaning) would provide moderate removal of TSS and metals, but the removal of metals is subject to a large range uncertainty. Alternative 1 has low technical feasibility due to uncertain performance, low reliability, and excessive maintenance requirements on the bridge. This alternative has the highest cost and is least cost effective due to low incremental removal capability.

Alternative 2 (catch basin filtration) has moderate removal of TSS and metals, but the removal of metals is subject to a large range of uncertainty. Alternative 2 also has low technical feasibility due to uncertain performance, low reliability, and excessive and unsafe maintenance requirements on the bridge. Alternative 2 has a moderate to low cost effectiveness.

Alternative 3 (modified catch basin/cleaning) provides relatively low removal of TSS and metals, has high technical feasibility, low cost, and low cost effectiveness.

Alternative 4 (high-efficiency sweeping and modified catch basin/cleaning) provides moderate amount of TSS and metal removal, high degree of technical feasibility, and appears the most cost effective for TSS and metals.

Table 3.2
Estimated Effectiveness of Alternatives

Constituent	Parameter	Current Loading Condition	Alternative 1: Media Filtration Vaults [a]		Alternative 2: Catch Basin Filtration[a]		Alternative 3: Modified Catch Basin/Cleaning		Alternative 4: High-Efficiency Sweeping and Modified Catch Basin/Cleaning	
Range of Estimated Effectiveness			**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Total Suspended Solids	Percent Reduction Range		81%	99%	81%	99%	49%	93%	70%	94%
	Mean Concentration in mg/L	94.40								
	Mass Reduction in lb/yr		11,007	13,387	11,007	13,387	6,695	12,591	9,416	12,760
Oil/Grease	Percent Reduction Range		46%	90%	46%	90%	25%	71%	30%	85%
	Mean Concentration in mg/L	9.47								
	Mass Reduction in lb/yr		627	1,217	627	1,217	342	966	413	1,157
Cadmium	Percent Reduction Range		45%	90%	45%	90%	23%	53%	55%	72%
	Mean Concentration in mg/L	0.005								
	Mass Reduction in lb/yr		0.32	0.64	0.32	0.64	0.16	0.38	0.40	0.52
Copper	Percent Reduction Range		44%	98%	44%	98%	25%	59%	47%	70%
	Mean Concentration in mg/L	0.022								
	Mass Reduction in lb/yr		1.41	3.15	1.41	3.15	0.81	1.89	1.49	2.25
Lead	Percent Reduction Range		60%	97%	60%	97%	43%	86%	64%	85%
	Mean Concentration in mg/L	0.022								
	Mass Reduction in lb/yr		1.87	3.04	1.87	3.04	1.35	2.70	2.00	2.68
Zinc	Percent Reduction Range		39%	97%	39%	97%	28%	64%	45%	70%
	Mean Concentration in mg/L	0.130								
	Mass Reduction in lb/yr		7.24	18.01	7.24	18.01	5.23	11.92	8.47	13.01

[a] Alternatives 1 and 2 will require a modified catch basin upstream of unit for pretreatment.

Table 3.3
Estimated Cost of Alternatives

	Alternative 1		Alternative 2		Alternative 3		Alternative 4	
	Media Filtration Vaults with Modified Catch Basin/Cleaning		Catch Basin Filtration		Modified Catch Basin/Cleaning		High-Efficiency Sweeping and Modified Catch Basin/Cleaning	
Range of Costs	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Capital Costs								
Modified Catch Basins	$480,000	$480,000	$480,000	$480,000	$480,000	$480,000	$480,000	$480,000
Vault with Media	$750,000	$750,000						
Boat for Vault Maintenance	$500,000	$1,000,000						
Flow Divider	$153,000	$153,000						
Conveyance piping	$1,992,000	$1,992,000	$150,000	$150,000				
Catch Basin Cartridge Units			$720,000	$720,000				
Mechanical Sweeper	$160,000	$160,000	$160,000	$160,000	$160,000	$160,000		
High-Efficiency Sweeper							$130,000	$275,000
Subtotal	*$4,035,000*	*$4,535,000*	*$1,510,000*	*$1,510,000*	*$640,000*	*$640,000*	*$610,000*	*$755,000*
Maintenance Cost								
Cartridge Replacement Filter	$28,560	$28,560	$25,200	$25,200				
Catch Basin Cartridge Maintenance			$66,440	$83,050				
Vault Maintenance	$55,520	$69,400						
Catch Basin Cleaning	$16,200	$34,400	$10,000	$20,000	$16,200	$34,400	$16,200	$34,400
Conventional Sweeping	$26,910	$26,910	$26,910	$26,910	$26,910	$26,910		
High-Efficiency Sweeping							$16,146	$64,584
Subtotal	*$127,190*	*$159,270*	*$128,550*	*$155,160*	*$43,110*	*$61,310*	*$32,346*	*$98,984*
I, annual interest rate	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
n, years	20	20	20	20	20	20	20	20
M, annual maintenance cost	$127,190	$159,270	$128,550	$155,160	$43,110	$61,310	$32,346	$98,984
C, initial capital cost	$4,035,000	$4,535,000	$1,510,000	$1,510,000	$640,000	$640,000	$610,000	$755,000
P, 20-year present worth	**$5,852,000**	**$6,810,000**	**$3,346,000**	**$3,727,000**	**$1,256,000**	**$1,516,000**	**$1,072,000**	**$2,169,000**

Insert

Figure 3.1

Cost Effectiveness of TSS Removal

Insert

Figure 3.2

Cost Effectiveness of Oil and Grease Removal

Insert
Figure 3.3
Cost Effectiveness of Cadmium Removal

Insert

Figure 3.4

Cost Effectiveness of Copper Removal

Insert

Figure 3.5

Cost Effectiveness of Lead Removal

Insert
Figure 3.6
Cost Effectiveness of Zinc Removal

3.2.3 Conclusions and Discussion of Proposed Treatment Alternative

The four technology alternatives were compared for reasonableness (technical feasibility and cost- effectiveness). They are ranked as follows:

- Alternative 4: High-efficiency sweeping and modified catch basin/cleaning
- Alternative 3: Modified catch basins/cleaning (with conventional sweeping)
- Alternative 2: Catch basin filtration (with conventional sweeping)
- Alternative 1: Media filtration vaults and modified catch basins/cleaning (with conventional sweeping)

Based on the ranking, Alternative 4: High-Efficiency Sweeping and Modified Catch Basin/Cleaning is the technology proposed for the floating bridge. This alternative appears to offer the most reasonable technologies for addressing water quality on the floating bridge based on technical feasibility and cost effectiveness. Alternative 4 has the following benefits for the proposed floating bridge:

- It can provide an effective level of water quality protection for sediments and metals.
- Its implementation is more visually apparent.
- It takes advantage of the bridge's flat gutterlines, which make it possible to retain sediments for longer periods, increasing the opportunity for their removal before they are discharged into catch basins.
- It does not have an unreasonable or unknown level of risk associated with operation and maintenance—a characteristic of the other technologies.

4. WATER QUALITY STUDY

This section of the report presents the following elements of the water quality study: approach assumptions, and limitation; modeling analyses of stormwater discharges; and discharge water quality evaluation.

4.1 APPROACH, ASSUMPTIONS AND LIMITATIONS

4.1.1 Study Approach

This project approach has been developed to respond to WSDOE's request to WSDOT for specific documentation of AKART and water quality analyses, and WSDOE's recent letter to WSDOT regarding documentation of compliance with water quality standards (White, 2002). Based on WSDOE's 1998 303(d) listing, Lake Washington waters meet all state water quality standards except those for bacterial pollution. Lake Washington waters are not listed for any metals or other constituents that may be contributed by stormwater runoff from a floating bridge. Therefore, this study has assumed that Lake Washington has assimilative capacity for the stormwater runoff from the replacement bridge.

The study approach and elements of this water quality study are as follows:

- Collect, summarize, and review relevant stormwater and Lake Washington water quality data. A technical memorandum listing available and relevant stormwater runoff data and Lake Washington water quality data was developed and submitted for review by WSDOT, WSDOE, WDFW, USFW, and NMFS for concurrence.

- Develop dilution models representing potential bridge stormwater discharges for the WSDOT's three floating bridge design alternatives. Because all stormwater flows have been designed to flow into a spill containment lagoon, dilution modeling methods have included volume-based calculations, vertical diffusion, and dispersion analyses. Dilution modeling has been developed for three runoff scenarios—the low-volume storm (10 percentile), mean annual storm (50 percentile), and the water quality treatment storm (91 percentile).

- Stormwater runoff discharge concentrations have been developed based on available data and FHWA protocols for highway runoff and recent Caltrans stormwater runoff data (Kayhanian, 2002).

- Stormwater runoff discharge concentrations have been evaluated using both total metals data and dissolved metals data. Where total metals data have been used to compare with the ambient water quality criteria for the protection of aquatic organisms (which are based on dissolved metals), the analysis has assumed that all metals discharged in the runoff are in the dissolved form. This is the most conservative approach to apply when site-specific metals data are not available to calculate a translator (dissolved/total metals ratio).

- Stormwater discharges to the receiving water body have been evaluated for compliance with acute and chronic chemical criteria in the state water quality standards. Stormwater runoff for each of the three bridge alternatives has been evaluated. Analyses have been limited to those parameters that FHWA lists as constituents of highway runoff.

- Preparation of a draft report for review by WSDOT and resource agencies.

- Meetings with WSDOT and resource agencies to discuss the findings presented in the draft report.

4.1.2 Assumptions and Limitations

The information contained in this report is based on the assumptions and limitations as documented in the project Scope of Work (Appendix A). The key assumptions and limitations are summarized below:

1. The analysis and conclusions documented in this report are limited to the proposed SR 520 replacement floating bridge

2. The pollutants of concern from highways are typically total suspended solids (TSS), oil and grease (O/G), cadmium, copper, lead, and zinc. The replacement SR 520 bridge would discharge stormwater runoff to Lake Washington, a SWMMWW-listed "basic receiving water body;" therefore, the target pollutant for treatment is TSS. TSS removal directly correlates to particulate metal removal. Stormwater runoff data on organic compounds such as petroleum hydrocarbons and polynuclear aromatic hydrocarbons were not available in the data sources for this study. Future monitoring by KCDNR on the SR 520 floating bridge includes plans to collect such data.

3. The Water Quality Standards for the Surface Waters of the State of Washington (WAC 173-201A) are the reference for determining water quality compliance of stormwater runoff. After stormwater has mixed with the lake, compliance is determined at appropriate distances from the point of discharge, referred to as mixing zone boundaries.

4. Projected discharge concentrations were compared with acute and chronic chemical criteria defined in the state water quality standards to provide a screening evaluation of protection of aquatic species (including salmonids) at the mixing zone boundaries. The bridge will discharge all stormwater into the spill containment lagoons and this will necessitate designation of mixing zones at distances from the point of discharge (i.e., where lagoons open at the base of the pontoons below the surface of the water).

5. The water quality treatment storm is based on the SWMMWW definition and as estimated by the Western Washington Hydrology Manual (WWHM) and the KCRTS method.

6. The portion of the bridge subject to the study is the roadway surface (vehicle lanes and shoulders) of the floating bridge. The proposed pedestrian/bicycle trail and pontoon deck

were not considered to be pollution-generating, and were therefore not included in this analysis.

4.2 MODELING ANALYSES OF STORMWATER DISCHARGES

The proposed stormwater drainage system for the replacement bridge is designed to discharge all runoff flows into the lagoons between the pontoons. Two types of drainage systems are under consideration for the replacement bridge design: one system would employ catch basins and the other involves vaults for stormwater treatment (Figure 2.1). The catch basin system would use catch basins under the roadway with vertical discharge pipes that terminate below the surface of the containment lagoons. The number and location of catch basins is shown in Figure 2.1 and on the drawings in Appendix B. The vault system would have vaults located on the cross pontoons. A vault would collect roadway runoff from an entire main pontoon and from a portion of the cross pontoon. The vaults would discharge into the ends of the containment lagoon, with two vaults discharging into each lagoon (Figure 2.1).

The volume of stormwater collected and discharged into the lagoons is effectively the same with the two systems. Table 2.1 provides a summary of the stormwater discharge system configurations and dimensions for both the catch basin and vault systems. This water quality study evaluated discharges from both systems for their effect in the lagoon and the adjacent lake.

4.2.1 Stormwater Discharge Scenarios

Three specific stormwater runoff scenarios were developed to represent a low-volume storm, a mean annual storm, and the water quality treatment storm. The low-volume storm is 10 percent of the discharge volume of the water quality treatment storm; this represents a dry season rainfall event. The mean annual storm is 50 percent of the water quality treatment storm; this represents an average rainfall runoff. The water quality treatment or design storm is the flow rate below which 91 percent of the runoff volume is generated (as estimated by WWHM or KCRTS model).

As described in Section 2, flow rates were estimated in accordance with the SWMMWW, using the 2-year flow from the KCRTS Model with its 15-minute time step. The water quality design storm flow was estimated by applying the SWMMWW ratio (Table 4-1 in the SWMMWW) to the KCRTS estimated 2-year flow, assuming 100-percent impervious area. In addition, stormwater quality design volumes (6-month, 24-hour storm), were calculated using the SCS Curve Number method (72 percent of the 2-year volume).

Table 4.1 shows the stormwater runoff and discharge scenarios for both catch basin and vault stormwater systems. These scenarios have been used in the dilution modeling analyses. Table 4.1 also provides the average stormwater runoff flow rate per catch basin or vault, the dimensions of the containment lagoons, the time required for the entire lagoon volume to fill (at the average runoff rate), and the volume-based dilution of the entire storm event flow in the lagoon. The total storm volumes have been used to calculate the volume-based dilutions in the containment lagoons. For all three stormwater runoff scenarios and all three bridge alternatives, the entire discharge volume is easily captured within the lagoons. It is also important to note that the containment lagoon depths (or drafts) used to calculate the lagoon volumes are the minimum lagoon depths, and therefore these are considered to provide a conservative representation of stormwater dilution in these lagoons.

The SWMMWW defines the water quality treatment storm as the storm runoff flow that necessitates traditional volume-based BMPs. Flow above the water quality treatment storm cannot be expected to be effectively treated and the concentrations of runoff constituents rapidly decrease with increasing storm event volumes. Table 4.2 shows the stormwater runoff volumes predicted for bridge alternatives for the 2-year, 10-year, 50-year, and 100-year return period storm events (non-treatment storm events). Table 4.2 also indicates that the proposed containment lagoon volumes for all three bridge alternatives are sufficiently large to capture the entire stormwater runoff volumes and provide dilution.

4.2.2 Discharge Modeling

4.2.2.1 Geometry and Processes

The spill containment lagoons for the bridge alternatives present a somewhat unique condition for discharge modeling, with mixing processes involving several active and passive stages. The mixing process stages are described in this section and a schematic of the mixing processes is presented in Figure 4.1. There are essentially three regions where several mixing processes will occur: (1) within the lagoon, (2) at the interface of the lagoon bottom and the lake, and (3) between the interface region and the defined mixing zone boundary.

The stormwater constituents in the bridge deck runoff will be treated for solids (particulates) removal and then discharged directly into the spill containment lagoon. The stormwater discharges into each lagoon will be conveyed directly below the lagoon surface through either multiple 8-inch vertical pipes (catch basin discharges) or through two 12-inch vertical pipes (vault discharges). The vertical drop from catch basins under the roadway deck to the pipe terminus below the water surface will range from 20 feet to more than 60 feet in some sections of the bridge (approach to high rise). These significant distances will create a gravity-induced discharge jet velocity for the stormwater discharged into the lagoons. This discharge jet velocity will provide immediate turbulent mixing of stormwater with lagoon water. In addition, the density difference between stormwater and lagoon water will enable entrainment of lagoon water into the stormwater (dilution), as well as density-driven diffusion in the lagoon. The individual lagoon depths (pontoon drafts) will vary from 12 to 22 feet depending on the size of the pontoon. The vertical discharge velocities will not be sufficient for the discharge plume to reach the bottom of the lagoon immediately.

Stormwater discharged into the spill containment lagoons will rapidly mix with the waters near the pipe ends, and will gradually diffuse throughout the entire contained volume through density-driven diffusion. At the same time that stormwater is discharged into the containment lagoon, water at the bottom of the lagoon will be displaced out the bottom of the lagoon and drawn into the ambient lake transport currents. The greater the discharge flow rate the higher the displacement of lagoon water. In addition, the greater the storm event winds, the greater the lake transport currents. Lake currents traveling across the base of the main pontoons will also generate turbulent flows or eddies across the bottom of the containment lagoons, and these will

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Table 4.2—8.5x11

Figure 4.1

Schematic Representation of Stormwater Mixing Processes increase mixing and displacement (refer to Figure 4.1). The lagoon water displaced or exiting the lagoon by turbulent mixing and diffusion will be rapidly diluted with the background lake water; the area where this dilution occurs is referred to as the interface region. Because the containment lagoons are long and narrow, and positioned perpendicular to the lake axis, the predominant lake currents will transport the diluted "plume" in a fashion similar to what is referred to as a "line plume" in dilution modeling. However, the line plume will be subject to turbulent mixing and vertical diffusion (downward) upon exiting the lagoon.

Beyond the interface region near the lagoon bottom, the diluting plume will be subject to vertical mixing and diffusion. Since the plume is under the bridge pontoon for 60 feet to 75 feet, the only vertical mixing will be downward until the outer edge of the pontoon is reached. The greater the density difference between the plume and the background lake water, the greater the rate of vertical mixing. A modification of the Brooks method to include vertical diffusion has been developed and applied in specific cases without vertical confinement, such as this project. This formulation has been incorporated into an Excel spreadsheet application by CH2M HILL and refined for application to near-surface or submerged plumes. The formulation, consistent with the Brooks method, assumes a line source of constant strength. The model accounts for vertical diffusion by applying a non-dimensional concentration reduction factor based on a Fickian diffusion coefficient (K_v). The lagoon interface mixing and vertical mixing model approach has been included in Appendix G.

4.2.2.2 Modeling Results

Table 4.3 presents dilution modeling results for each bridge alternative, runoff storm scenario, and for both catch basin and vault stormwater systems. Within the spill containment lagoon, dilutions are shown for three phases during a storm event: after 25, 50, and 100 percent of the storm flow has mixed into the lagoon. This progressive series of dilutions in the containment lagoon shows the gradual decrease in constituent dilution until the storm event is concluded. The dilution results are the ratio of the receiving water to stormwater. For example, the results for the water quality treatment storm with the 6-lane alternative shows the dilution inside the containment lagoon starting at 23:1 and ending at 12:1 at the storm end. This dilution prediction is conservative because it assumes that none of the stormwater is lost from the lagoon. In actual conditions, the lagoon water displaced by the stormwater discharge would include an increasing portion of the stormwater that would mix and exit the lagoon during the storm event.

The dilutions predicted at the lagoon interface with the lake are based on calculations of immediate turbulent mixing and diffusion with the ambient lake water, and these represent the dilutions at a distance of 10 feet from the lagoon opening. Following the immediate mixing at the interface region, the vertical mixing process and diffusion expand the plume downward. The 100-foot distance to a proposed mixing zone boundary is assumed in this analysis, and this represents a minimal mixing zone distance.

Predicted dilutions for the water-quality treatment storm event range from 90 (8-lane alternative) to 189 (4-lane alternative), at the mixing zone boundary. The narrower containment lagoons with the 4-lane and 6-lane alternatives provide less volume for mixing within the lagoon, but they present a narrower line plume exiting the bottom of the lagoon, which increases the immediate mixing at the lagoon interface region. Conversely, the 8-lane alternative provides a much larger containment lagoon volume and wider line plume with lower immediate mixing.

4.2.3 Mixing Zones

Based on the dilution modeling analyses developed in this water quality study, the replacement bridge for SR 520 will require defined mixing zones for acute and chronic criteria compliance to address stormwater treatment upset conditions and maximum storm flow loads. In accordance with WAC 173-201A-100(10)(b), the WSDOT replacement bridge would qualify for an exemption to the numeric size criteria for lake mixing zones. WSDOE could permit mixing zones for the replacement bridge if the following are demonstrated to WSDOE satisfaction:

> "(i) All appropriate best management practices established for stormwater pollutant control have been applied to the discharge; [recognizing floating bridge constraints]
>
> (ii) The proposed mixing zone shall not have a reasonable potential to result in a loss of sensitive or important habitat, substantially interfere with the existing or characteristic uses of the water body, result in damage to the ecosystem, or adversely affect public health as determined by the department; and
>
> (iii) The proposed mixing zone shall not create a barrier to the migration or translocation of indigenous organisms to a degree that has the potential to cause damage to the ecosystem.

Subsequent environmental documentation will be required to substantiate the WSDOT request for stormwater mixing zones; however, the analyses presented in this water quality report show that the acute and chronic criteria can be met through the application of the selected AKART stormwater treatment alternative and reasonably small areas for acute and chronic mixing zones. Figure 4.2 provides a schematic section view of the proposed acute and chronic mixing zone boundaries for each of the bridge alternatives. The proposed stormwater chronic mixing zone is a 100-foot radius from the center of each containment lagoon. The location and size of a proposed zone of acute criteria exceedance would need to include the entire containment lagoon, and it is proposed to extend a distance of 10 feet from the edge of the containment lagoon (Figure 4.2). Figure 4.3 provides a plan view of each alternative bridge layout (4 lanes, 6 lanes, and 8 lanes) and the extent to which the chronic mixing zone boundaries would extend beyond the bridge structure.

4.3 DISCHARGE WATER QUALITY EVALUATION

The stormwater runoff data, background receiving water data, and dilution modeling results are applied in this section to evaluate the stormwater discharge compliance with acute and chronic criteria for the protection of aquatic life in Lake Washington.

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Insert Figure 4.2—8.5x11

Insert Figure 4.3—8.5x11

4.3.1 Stormwater Runoff and Background Data

4.3.1.1 Stormwater Event Concentrations

As described in Section 2, stormwater runoff discharge concentrations have been developed based on available data and FHWA protocols for highway runoff and recent Caltrans stormwater runoff data (Kayhanian, 2002). The stormwater EMC values for copper, lead, and zinc have been used to represent the average stormwater discharge concentrations in this water quality study. These are considered to be reasonable and conservative metals estimates. The available database of stormwater cadmium values is more limited than for other constituents, and to be conservative the maximum cadmium value from the Caltrans highway stormwater runoff data was used. The stormwater runoff discharge concentrations used in this study are listed below:

- Cadmium: 5 micrograms per liter (ug/L)
- Copper: 22.3 ug/L
- Lead: 21.9 ug/L
- Zinc: 129.8 ug/L

4.3.1.2 Background Lake Washington Data

King County's Department of Natural Resources has conducted substantial and detailed water quality sampling throughout Lake Washington. Three of the King County Department of Natural Resources (KCDNR) routine sampling sites are located in the central basin of the lake and away from shoreline runoff sources: one is north of the I-90 bridge (Site 890), another is north of the elevated structure on the Evergreen Point bridge (Site 852), and the other is located off Sand Point (Site 826). Seasonal sampling at these sites has included water column vertical profile measurements and water samples at surface, middle, and near-bottom depths for nutrients, metals, and chlorophyll. Ambient monitoring data for autumn 2000 (dry season) and winter 2001 (wet season) were provided by KCDNR. Metals data (total and dissolved) for these three sampling sites in central basin of Lake Washington are summarized in Appendix H of this report. The median total metals data have been used in this evaluation to represent background metals concentrations in the lake because these total metals data represent the highest potential metals concentration and not just the bioavailable dissolved fraction. The total metals values that were used in this analysis and assumed to be dissolved metals values are listed below along with the actual dissolved metals concentrations measured by KCDNR:

- Total cadmium—0.01 ug/L; dissolved cadmium—0.01 ug/L
- Total copper—0.99 ug/L; dissolved copper—0.86 ug/L
- Total lead—0.025 ug/L; dissolved lead—0.025 ug/L

- Total zinc—0.7 ug/L; dissolved zinc—0.7 ug/L

4.3.2 Stormwater Discharge Evaluations

Stormwater constituent metals of concern include cadmium, copper, lead, and zinc. These metals have various sources from roadway vehicular traffic. Stormwater runoff metals concentrations have been applied in a series of spreadsheets to calculate the metals concentrations predicted within the containment lagoons for bridge alternatives, and at selected distances away from the containment lagoon. This screening level evaluation applies the dilution predictions developed in the previous sections. Stormwater treatment of the bridge runoff was assumed to be the low range of the estimated effectiveness (removal efficiency) for Alternative 4 (high-efficiency sweeping and modified catch basin/cleaning) shown in Table 3.2. Background metals data for Lake Washington have been added to the stormwater runoff concentration to represent the combined concentration.

Stormwater runoff discharge concentrations have been evaluated using both total metals data and dissolved metals data. When total metals data have been used to compare with the ambient water quality criteria for the protection of aquatic organisms (which are based on dissolved metals), the analyses have assumed that all metals discharged in the runoff are in the dissolved form. This is the most conservative approach to apply when site-specific metals translator data are not available.

The acute and chronic chemical criteria have been calculated using the method defined in WAC 173-201A-040, assuming the minimum ambient lake water hardness of 38 milligrams per liter (mg/L). These calculated acute and chronic criteria for cadmium, copper, lead, and zinc have been compared directly with the predicted metals concentrations within the containment lagoons for the bridge alternatives, and at selected distances away from the containment lagoon.

4.3.2.1 Cadmium

EPA recently published a 2001 Update of Ambient Water Quality Criteria for Cadmium (EPA, 2001). This new document specifies lower acute and chronic criteria for the protection of aquatic life than the existing acute and chronic chemical criteria defined in the Surface Water Quality Standards for Washington (WAC 173-201A-040). EPA's new criteria will become part of the state water quality standards by direct incorporation or by default in future years. Both the existing criteria in the state water quality standards and the new EPA cadmium criteria have been presented in Table 4.4 to assess current and future compliance with cadmium criteria.

The predicted cadmium concentrations following discharge to the containment lagoons are summarized in Table 4.4, assuming the minimum or low range of the estimated removal efficiency for stormwater treatment Alternative 4 (55 percent removal for cadmium). These results show that predicted runoff concentrations from the water quality treatment storm for the 4- and 6-lane bridge alternatives could result in cadmium concentrations within the lagoon less than either acute criteria, but could exceed the EPA revised chronic criteria. The runoff concentration for the water quality treatment storm from the 8-lane alternative would not exceed any criteria. Table 4.4 shows that the predicted cadmium concentrations at 10 feet beyond the

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lagoon and 100 feet beyond the lagoon would be less than both acute and chronic criteria. These screening level results indicate that stormwater discharges can achieve the water quality standards, assuming acute and chronic mixing zone boundaries of 10 feet and 100 feet, respectively, from the lagoon opening.

4.3.2.2 Copper

Copper concentrations following discharge to the containment lagoons are summarized in Table 4.5, assuming the low end of the estimated removal efficiency for Alternative 4 (47 percent removal of copper), as shown in Table 3.2. These analyses show that with the water quality treatment storm flows and the lower storm flows, the copper concentrations within the lagoon would not exceed either the acute or chronic criteria for copper. Table 4.5 shows that the predicted copper concentrations would diminish rapidly at 10 feet and 100 feet beyond the lagoon, and the copper concentrations would meet acute and chronic criteria for all discharge scenarios.

4.3.2.3 Lead

Predicted lead concentrations following discharge to the containment lagoons are summarized in Table 4.6. The stormwater discharge concentrations to the lagoon have assumed the minimum estimated removal efficiency for Alternative 4 (64 percent removal for lead), as shown in Table 3.2. These analyses show that the acute criteria for lead would not be exceeded under any of the storm flow scenarios. The stormwater runoff concentrations of lead could exceed the chronic criteria inside the containment lagoon with water quality treatment storm flows for the 4- and 6-lane alternatives. Table 4.6 also shows that the lead concentrations at 10 feet beyond the lagoon are predicted to be less than the acute and chronic criteria, for all discharge scenarios. At 100 feet beyond the discharge point in the lagoon the lead concentrations would also meet all criteria.

4.3.2.4 Zinc

Zinc concentrations following discharge to the containment lagoons are summarized in Table 4.7, assuming the minimum estimated removal efficiency for Alternative 4 (45 percent removal for copper), as shown in Table 3.2. These analyses show that the acute and chronic criteria for zinc can be achieved within the lagoon for all alternatives. Therefore, the acute and chronic criteria will be achieved at 10 and 100 feet beyond the lagoon, for all discharge scenarios.

4.3.3 Review of Stormwater Runoff and AKART Treatment Effectiveness

A series of analyses have been developed in this section to delineate clearly where the stormwater discharge meets water quality criteria both without and with the application of the four AKART treatment alternatives and for both total and dissolved metals. An analysis has also been developed to quantify how the stormwater runoff metals concentrations are affected by changes in the maintenance frequency of the AKART alternatives. These analyses have all been developed using the discharge flows and dilutions for the water quality treatment storm with the 6-lane bridge alternative. In addition, an analysis has been developed that provides a direct comparison of the estimated loading rates of pollutants for the existing SR 520 bridge with the proposed replacement bridge alternatives, using equivalent bridge section lengths.

As a first step in the evaluation of stormwater runoff treatment requirements and effectiveness needed to meet the state water quality standards, a screening analysis was prepared for the discharge of untreated stormwater runoff from the proposed replacement bridge (Table 4.8). The screening analyses for untreated stormwater were developed using the discharge flows and dilutions for the water quality treatment storm based on the 6-lane bridge alternative.

Table 4.8a shows the acute and chronic water quality criteria, and Table 4.8b summarizes the total metals concentrations in the untreated stormwater runoff, in the discharge pipe entering the spill control lagoon, in the spill control lagoon (at the end of the storm event), at the proposed acute mixing zone boundary (10 feet beyond the bottom of the lagoon opening), and at the proposed chronic mixing zone boundary (100 feet beyond the lagoon opening). The shaded cells in Table 4.8b identify those metals and locations that do not meet the water quality criteria, and the unshaded cells represent attainment of the water quality criteria. The screening evaluation results show that the *untreated* stormwater runoff levels of copper and zinc could meet the acute and chronic water quality criteria after mixing in the lagoon, and that cadmium (assuming future criteria) and lead could meet the acute and chronic water quality criteria with the dilutions achieved at the acute and chronic mixing zone distances. As note previously, this compliance evaluation assumes that all metals discharged into the receiving waters are in the dissolved form.

4.3.4 AKART Alternatives Treatment Effectiveness and Water Quality Criteria

Total Metals Four AKART treatment alternatives were selected for detailed evaluation in this study, and a range of treatment efficiencies have been calculated for these four alternatives. Table 4.9 presents a series of three tables (4.9a, 4.9b, and 4.9c) that have been used to calculate the estimated metals concentrations in the bridge stormwater runoff using the minimum, average, and maximum treatment removal efficiency. Table 4.9a shows the acute and chronic water quality criteria, and Table 4.9b provides the range of metal-specific removal efficiencies for each AKART treatment alternative. Table 4.9c summarizes the total metals concentrations at the following points: in the untreated stormwater runoff, in the discharge pipe entering the spill control lagoon (immediately following treatment), in the spill control lagoon (at the end of the storm event), at the proposed acute mixing zone boundary (10 feet beyond the bottom of the lagoon opening), and at the proposed chronic mixing zone boundary (100 feet beyond the lagoon opening).

The shaded cells in Table 4.9c identify those metals and locations that do not meet water quality criteria, and the unshaded cells represent attainment of water quality criteria. These results demonstrate that once the stormwater runoff has been treated (applying any of the four treatment alternatives) and discharged into the spill containment lagoon, then the metals

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Table 4.8 – 8 1/2 x11 one page (NEW)

concentrations are estimated to be below the acute criteria level in all cases and below the chronic criteria level for some of the average and maximum removal efficiencies. This analysis shows that only cadmium (applying the future criteria) and lead require additional mixing to meet the chronic water quality criteria at the point of discharge to the lagoon. At the proposed acute mixing zone boundary all metals are shown to meet the acute criteria and only cadmium shows the potential to require additional dilution to meet the chronic criteria. This compliance evaluation assumes that all runoff metals concentrations discharged into the receiving waters are in the dissolved form, the most conservative analysis approach.

Dissolved Metals Dissolved metals are the bio-available form of metals in water, and the acute and chronic criteria for the protection of aquatic organisms are based on dissolved metals. An analysis was developed to focus specifically on the dissolved metals portion of stormwater runoff. The partitioning of metals in highway runoff has been addressed in the Caltrans 2000-2002 study (Kayhanian, et. al., 2002) and in a technical report developed by the U.S. Geological Survey (Breault and Granato, 2000). The Caltrans study reports both dissolved and total metals concentrations for the 31 highway sites and 192 storm samplings. The percent dissolved metals to total metals in the Caltrans study are as follows: cadmium 57 percent, copper 51 percent, lead 14 percent, and zinc 46 percent. When these dissolved/total metals ratios are compared to a wide range of stormwater studies reviewed in the U.S. Geological Survey report (Breault and Granato, 2000), these ratios prove to be mid-range for each metal. Therefore, the dissolved to total metals ratios in the Caltrans study are a good representation of average stormwater metals.

Table 4.10 presents a series of four tables (4.10a, 4.10b, 4.10c, and 4.10d) that have been used to calculate the estimated *dissolved metals* concentrations in the stormwater runoff using the estimated dissolved metals fraction in runoff and average dissolved metals treatment removal efficiencies for the four AKART alternatives. Table 4.10a shows the acute and chronic water quality criteria. Table 4.10b applies the measured percent dissolved metals to total metals to calculate the dissolved metals concentration assumed in the stormwater runoff. Table 4.10c lists dissolved metals removal efficiencies for each AKART treatment alternative, and these range from zero removal for Alternatives 3 and 4 to 15 or 16 percent removal for Alternatives 1 and 2. These estimates of dissolved metals concentrations and removal efficiencies were applied to calculate the dissolved metals concentrations in the stormwater runoff for the water quality treatment storm with the 6-lane bridge alternative.

Table 4.10d summarizes the calculated dissolved metals concentrations in the untreated stormwater runoff, in the discharge pipe entering the spill control lagoon (immediately following treatment), in the spill control lagoon (at the end of the storm event), at the proposed acute mixing zone boundary (10 feet beyond the bottom of the lagoon opening), and at the proposed chronic mixing zone boundary (100 feet beyond the lagoon opening).

The shaded cells in Table 4.10d identify the metals and locations that do not meet the acute or chronic water quality criteria, and the unshaded cells represent attainment of the water quality criteria. These results demonstrate that once the dissolved metals in the stormwater runoff have

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been treated (applying any of the four treatment alternatives) and discharged into the spill containment lagoon, then the dissolved metals are estimated to be below the acute criteria level in all cases and below the chronic criteria level for all metals except cadmium (applying the future criteria). At the proposed acute zone boundary all dissolved metals are calculated to meet the acute and chronic criteria.

AKART Alternative 4 – Maintenance Effectiveness Four AKART treatment alternatives were selected for detailed evaluation in this study, and Alternative 4 (high-efficiency sweeping and modified catch basin/cleaning) was recommended in this report for the replacement bridge. The relationship between the frequency of applying the Alternative 4 maintenance methods (catch basin cleaning and roadway sweeping) and the effectiveness of the removing metals from the stormwater runoff are evaluated in Table 4.11.

Table 4.11 presents a series of three tables (4.11a, b, and c) that have been used to calculate the estimated metals concentrations in the bridge stormwater runoff using a range of maintenance efforts for AKART Alternative 4. Table 4.11a shows the acute and chronic water quality criteria, and Table 4.11b provides the range of metal-specific removal efficiencies for each maintenance option. Table 4.11c summarizes the total metals concentrations at the following points: in the untreated stormwater runoff, in the discharge pipe entering the spill control lagoon (immediately following treatment), in the spill control lagoon (at the end of the storm event), at the proposed acute mixing zone boundary (10 feet beyond the bottom of the lagoon opening), and at the proposed chronic mixing zone boundary (100 feet beyond the lagoon opening).

The shaded cells in Table 4.11c identify those metals and locations that do not meet the water quality criteria, and the unshaded cells represent attainment of the water quality criteria. These results demonstrate that with annual catch basin cleaning and monthly roadway sweeping, the stormwater runoff discharged into the spill containment lagoon would be less than the acute and chronic criteria levels for all metals except cadmium (applying the future criteria). At the proposed acute zone boundary all metals are shown to meet the acute criteria and chronic criteria. Again, this compliance evaluation assumes that all runoff metals concentrations discharged into the receiving waters are in the dissolved form, the most conservative analysis approach.

4.3.4.1 Comparison of Stormwater Loading Rates – Existing and Future

An analysis has been developed that provides a direct comparison of the estimated loading rates of pollutants for the existing SR 520 bridge compared with the proposed replacement bridge alternatives. This analysis used equivalent bridge section lengths (420 feet) and bridge widths that were specific to the existing bridge and the three replacement bridge alternatives. The BMP removal efficiencies applied in this analysis assume bi-monthly conventional roadway sweeping on the existing SR 520 bridge, and the average removal for AKART Alternative 4 with the replacement bridge alternatives. Table 4.12 shows the complete series of pollutant loading calculations for this analysis and the bottom section of the table (annual mass loading) presents the results for TSS, O/G, and four metals.

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TSS in stormwater runoff from the existing SR5 20 bridge is estimated at 95 lb/yr (per section) compared to 45 lb/yr for the 4-lane alternative, 71 lb/yr for the 6-lane alternative, and 86 lb/yr for the 8-lane alternative (Table 4.12). The estimated O/G loads are equivalent for the existing SR 520 bridge and the 4-lane alternative, but higher for the 6- and 8-lane alternatives. The estimated mass loads for cadmium, copper, and lead do not show an increase for any of the bridge alternatives compared to the existing SR 520 bridge. The estimated mass loads for zinc on the 4- and 6-lane alternatives are equivalent to the existing SR 520 bridge, and the 8-lane alternative shows a projected 20-percent increase over the existing load. It is important to recognize that road surface areas of the 4-, 6-, and 8-lane bridge alternatives are greater than the road surface area of the existing SR5 20 bridge (equivalent bridge length) by 46, 132, and 180 percent, respectively. These large increases in road surface areas with little or no increase in annual mass loadings illustrates the effectiveness of the proposed AKART Alternative 4 treatment measures.

4.3.5 Conclusions

The key objective of this water quality study was to provide an evaluation of the water quality of the stormwater runoff from a new bridge, and document whether the stormwater discharges are projected to meet state water quality standards. The conclusions of this study are as follows:

- Spill containment lagoons in the replacement floating bridge designs will meet the high priority of roadway spill containment without compromising the bridge structural limitations.
- Spill containment lagoons will provide a benefit in stormwater discharge management by capturing the runoff and then metering the diluted stormwater into the lake over time.
- The spill containment lagoon sized for the 8-lane alternative provides potentially greater benefit than the smaller sized lagoons for the 4- and 6-lane alternatives, because of the additional containment volume.
- The result of the modeling analyses and discharge evaluations of key stormwater metals shows that cadmium and lead concentrations pose the greatest challenge to meeting water quality standards, and these will require stormwater treatment as defined in the AKART evaluation as well as the application of acute and chronic mixing zones.
- Future revisions to the acute and chronic chemical criteria in the state water quality standards and new stormwater quality data for existing floating bridges (as planned by KCDNR) could change the determination of whether other metals would require partial removal.
- Acute and chronic criteria for metals (total and dissolved) can be met through the application of the selected AKART stormwater treatment alternative and reasonably

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- small acute and chronic mixing zone sizes. Additional environmental documentation will be needed to support the development of stormwater mixing zones for the replacement bridge.

- The proposed maintenance frequency for AKART Alternative 4 is calculated to result in stormwater runoff levels in the spill containment lagoon less than the acute and chronic criteria levels for all metals except cadmium (based on the future criteria for cadmium). At the proposed acute zone boundary all metals are predicted to meet the acute criteria and chronic criteria; and

- The three replacement bridge alternatives would have little or no increase in annual mass loadings of TSS and metals, compared to the existing SR 520 bridge, because of the effectiveness of the proposed AKART Alternative 4 treatment measures.

5. CONCLUSIONS

The four technology alternatives were compared for reasonableness (technical feasibility and cost- effectiveness). They are ranked as follows:

- Alternative 4: High-efficiency sweeping and modified catch basin/cleaning
- Alternative 3: Modified catch basins/cleaning (with conventional sweeping)
- Alternative 2: Catch basin filtration (with conventional sweeping)
- Alternative 1: Media filtration vaults and modified catch basins/cleaning (with conventional sweeping)

Based on the ranking, Alternative 4: High-Efficiency Sweeping and Modified Catch Basin/Cleaning is the technology proposed for the floating bridge. This alternative appears to offer the most reasonable technologies for addressing water quality on the floating bridge based on technical feasibility and cost effectiveness. Alternative 4 has the following benefits for the proposed floating bridge:

- It can provide an effective level of water quality protection for sediments and metals.
- Its implementation is more visually apparent.
- It takes advantage of the bridge's flat gutterlines, which make it possible to retain sediments for longer periods increasing the opportunity for their removal before they are discharged into catch basins.
- It does not have an unreasonable or unknown level of risk associated with operation and maintenance—a characteristic of the other technologies.

The water quality study portion of this report concluded that:

- Spill containment lagoons in the replacement floating bridge designs will meet the high priority of roadway spill containment without compromising the bridge structural limitations.
- Spill containment lagoons will provide a benefit in stormwater discharge management by capturing the runoff and then metering the diluted stormwater into the lake over time.
- The spill containment lagoon sized for the 8-lane alternative provides potentially greater benefit than the smaller sized lagoons for the 4- and 6-lane alternatives, because of the additional containment volume.
- The result of the modeling analyses and discharge evaluations of key stormwater metals shows that cadmium and lead concentrations pose the greatest challenge to meeting water quality standards, and these will require stormwater treatment as defined in the AKART evaluation as well as the application of acute and chronic mixing zones.

- Future revisions to the acute and chronic chemical criteria in the state water quality standards and new stormwater quality data for existing floating bridges (as planned by KCDNR) could change the determination of whether other metals would require partial removal.

- Acute and chronic criteria for metals can be met through the application of the selected AKART stormwater treatment alternative and reasonably small acute and chronic mixing zone sizes.

- The proposed maintenance frequency for AKART Alternative 4 is calculated to result in stormwater runoff levels in the spill containment lagoon less than the acute and chronic criteria levels for all metals except cadmium (based on the future criteria). At the proposed acute zone boundary all metals are predicted to meet the acute criteria and chronic criteria.

- The three replacement bridge alternatives would have little or no increase in annual mass loadings of TSS and metals, compared to the existing SR 520 bridge, because of the effectiveness of the proposed AKART Alternative 4 treatment measures.

- Additional environmental documentation will be needed to support the development of stormwater mixing zones for the replacement bridge.

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APPENDIX A

WSDOE Memorandum and Project Team Scope of Work

WSDOE MEMORANDUM

Following the February 28, 2002 meeting between Ecology and WSDOT to discuss stormwater treatment for the SR-520 Bridge, WSDOT agreed to develop two reports:

1) An AKART analysis of the options for treating stormwater from the Bridge; and 2) A water quality report detailing the water quality of the expected runoff from the Bridge. The following provides information regarding the two reports.

1. **AKART Report**:

The first **report is a top-down AKART analysis** of water pollution control technology that can be used to treat and minimize stormwater pollution in Lake Washington from the 520 Bridge wastewater discharges. This includes: the traditional methods known and available to treat stormwater; and methods found through a literature search. A principal source for the technologies that should be reviewed may be the technologies contained in the Stormwater Management Manual for Western Washington.

If Ecology is assured that a pollution control technology is not applicable to the floating portion of the Bridge then the next level of treatment technology will be reviewed.

> **NOTE!** For the AKART report, Ecology agrees to a few design constraints that are unique to floating bridges that could narrow down the AKART analysis. The agreement is subject to adequate documentation by WSDOT.
>
> - Treatment options that could lead to ponding of water on the roadway surface do not need to be considered. (This is based on WSDOT documenting traffic safety considerations and possibly bridge structural/stability considerations.)
> - Treatment options that involve storing significant volumes of water on the bridge do not need to be extensively considered. (This is based on WSDOT documentation of bridge structural and integrity problems as well as the Blue ribbon report.)
> - Treatment options that rely in settling of solids do not need to be extensively considered. (This is based on WSDOT documentation of typical bridge movement during storms and under normal operations would hinder settling.)
> - Treatment options that rely on collecting and pumping stormwater do not need to be extensively considered. (This is based on WSDOT documentation of the O&M costs in addition to the difficulty of collecting/storing water to make a pump system work.)

Details of the AKART analysis:

Step 1--Identify All Control Technologies,

This includes not only existing controls for floating bridges but also through technology transfer controls applied to similar source categories e.g. floating dry docks. This includes technologies employed outside the United States. For example, Caltrans treats pollution in highway stormwater discharges with catch basins, settling chambers, oil sorbent pads using sand followed by ion exchange.

Step 2--Eliminate Technically Infeasible Options

A demonstration of technical infeasibility should be clearly documented and should show, based on physical, chemical and engineering principles, that the technical difficulties would preclude the successful use of the control option for the floating portion of the bridge.

Step 3--Rank Remaining Control Technologies by Control Effectiveness

This list includes control effectiveness for each pollutant characterized for the contaminated wastewater and should include the following types of information.

A. control efficiencies (percent pollutant removed)

B. expected discharge concentrations

C. expected pollutant reduction

D. An analysis of pollutant removal costs in terms of cost per pound of pollutant removed.

Step 4 Evaluate Most Effective Control and Document Results

Upon completion of the AKART analysis, Ecology will evaluate the report and, if any of the steps are incomplete, then the analysis is incomplete and Ecology will not commit to the proposed stormwater treatment design.

2. Water Quality Report:

The **second report** is a water quality report detailing the water quality of the expected runoff from the bridge. WSDOT should use pollutant values for untreated stormwater runoff based on the ADT for the different bridge options. The untreated runoff values would be reduced based on the treatment option proposed as part of the AKART report to produce treated stormwater pollutant loadings/concentrations discharged to the lake. Using dilution models and any available information on background concentrations in the Lake, WSDOT then needs to estimate pollutant concentrations at points 10 feet and 100 feet from the bridge and compare the estimated lake concentrations against the state water quality standards.

Next Steps: Following completion of the above two reports, WSDOT will submit them to Kevin Fitzpatrick at Ecology's NW Regional office and Bill Moore at Ecology's Headquarters who will be responsible for disseminating the information to the other Ecology staff.

Terry Swanson will work with Paul Krueger to arrange a field trip to the Hood Canal Bridge (for comparison purposes) and the SR-520 Bridge. The field trip will occur following receipt of the stormwater treatment documents.

Terry Swanson will organize a resource agency meeting to discuss the two reports and the field trip.

Following that meeting, the resource agencies will meet with WSDOT to discuss the information. Terry and Paul will organize that meeting.

At that meeting, or shortly thereafter, WSDOT hopes for a commitment from the resource agencies regarding the proposed stormwater treatment design.

Excerpt from Agreement Y-6974, Work Order #7 – (August 19, 2002)

8.4—Preliminary Design Studies

8.4.5.4—AKART and Water Quality Study

The Washington State Department of Transportation (STATE) and their engineering consultants are developing design alternatives and environmental documentation to replace the SR 520 floating bridge. On February 28th, 2002, STATE met with the Washington State Department of Ecology (Ecology), National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife (USFW), and the Washington State Department of Fish and Wildlife (WDFW) to discuss stormwater design and permitting issues. Following this meeting, Ecology sent STATE a memo specifying which analyses they would require to come to a decision on stormwater treatment on the bridge. These analyses are: an AKART ("All Known Available and Reasonable Treatment") Report to evaluate stormwater treatment options, and a Water Quality Report to evaluate the water quality of the stormwater runoff from a new bridge and its concentrations after mixing with lake water. This scope of work presents project objectives and approach, project assumptions, and specific work tasks for developing these two documents.

Objectives: The project objectives for the Stormwater AKART and Water Quality Study are to:

- Develop and implement a project approach that meets the STATE objectives for stormwater treatment and discharge options, and also meets with Ecology approval;
- Develop an AKART Report that will provide an evaluation of stormwater treatment options, and define and document the design constraints and feasible stormwater engineering options for a new floating bridge;
- Develop a Water Quality Report that will provide an evaluation of the water quality of the stormwater runoff from a new bridge, and will document how the stormwater discharges are projected to meet state water quality standards; and
- Communicate the results of the AKART and Water Quality Report to STATE, Ecology and other agencies.

This project approach has been developed to respond to Ecology's request to STATE for specific documentation of AKART and water quality analyses, and Ecology's recent letter to STATE regarding documentation of compliance with water quality standards ("Comments on Guidance on Early Action Mitigation Proposal for I-405," Letter from Megan White, Ecology Water Quality Program Manager to Bruce Smith, WSDOT, dated March 14, 2002). Based on Ecology's 1998 303(d) listing, Lake Washington waters meet the state water quality standards, with the exception of bacterial pollution. Lake Washington waters are not listed for any metals that may be contributed by stormwater runoff from the floating bridge. Therefore, this study will assume that Lake Washington has assimilative capacity for the stormwater runoff.

Assumptions: The following lists the assumptions for the Stormwater AKART and Water Quality Study:

1. WSDOE's Stormwater Management Manual for Western Washington (SWMMWW), August 2001, will be used as a primary reference for water quality treatment BMPs. This information will be supplemented from five other sources: an Internet search; a literature search using Dialogue databases; information derived from vendors; information derived from selected state and federal transportation agencies; and data provided by WSDOE and EPA. Technology identification will be limited to the information collected using the sources identified above, within the level-of-effort identified to accomplish the scope of services.

2. The pollutants of concern from highways are typically total suspended solids (TSS), oil and grease, cadmium, copper, lead, and zinc. The new SR 520 bridge would discharge stormwater runoff to Lake Washington, a listed "basic receiving water body" in SWMMWW, and therefore the target pollutant for treatment is TSS. TSS removal directly correlates to particulate metal removal. This analysis will therefore focus on technologies that remove TSS and particulate metals. Technologies specifically aimed at removing dissolved metals will not be evaluated in this analysis.

3. The Water Quality Standards for the Surface Waters of the State of Washington (WAC 173-201A) will be the reference for determining water quality compliance of stormwater runoff, at appropriate distances following mixing with lake water. Background Lake Washington water quality data will be based on King County DNR monitoring data, Ecology's monitoring data, and other available data sources with data quality assurance records. Background lake water quality data will be limited to the sources identified above, within the level-of-effort identified to accomplish the scope of services.

4. Projected discharge concentrations will be compared with acute and chronic chemical criteria defined in the state water quality standards to provide a screening evaluation of protection of aquatic species (including salmonids) beyond the mixing zone boundaries.

5. The water quality treatment storm is the 6-month, 24-hour SBUH storm for traditional volume-based BMPs. For flow-based structural BMPs, the water quality treatment storm is the flow rate below which 91 percent of the runoff volume is generated (as estimated by WWHM or KCRTS, a locally available model).

6. The portion of the bridge subject to the study is the roadway surface (vehicle lanes and shoulders) of the floating bridge. The proposed pedestrian/bicycle trail and pontoon deck will not be considered pollution-generating, and thus will not be included in this analysis.

7. Stormwater discharge designs for the three build alternatives will be provided by STATE. Design information will include inlet and discharge locations, pipe outlet diameters, preliminary bridge layout, and pontoon geometry.

8. No pilot or treatability studies will be conducted as part of this analysis.

9. Untreated pollutant loads will be based on available FHWA and bridge-related data (e.g., Driscol 1990; NCHRP) and King County DNR data (if available).

10. WSDOE agrees to a few design constraints unique to floating bridges that could narrow the AKART analysis. This is subject to adequate documentation in the AKART, similar to that provided for the Hood Canal Bridge. These include these conditions, limitations, and restrictions:

A. Treatment options that could lead to ponding of water on the roadway surface do not need to be considered. (when documented with traffic safety considerations and possibly bridge structural/stability considerations.)

B. Treatment options that involve storing significant volumes of water on the bridge do not need to be extensively considered. (when documented with bridge structural and integrity problems and the Blue Ribbon Panel report.)

C. Treatment options that rely in settling of solids do not need to be extensively considered. (when documented with typical bridge movement during storms and under normal operations would hinder settling.)

D. Treatment options that rely on collecting and pumping stormwater do not need to be extensively considered. (when documented with O&M costs and the difficulty of collecting/storing water for a pump system.)

STATE will provide the above documentation to CONSULTANT for inclusion in AKART report.

Approach: AKART Report: The following tasks will be conducted to prepare the AKART Report, and to communicate the approach and findings.

- Confirm Study Approach with Agencies. The draft scope of work will be submitted to Ecology for concurrence and approval. A meeting will be held with Ecology (if necessary) to review the scope of work and approach.

- Collect Data and Identify and Screen Source Reduction and/or Treatment Technologies.

- Review SWMMWW. Ecology's new stormwater manual will be reviewed to identify known and applicable treatment technologies.

- Conduct literature searches. Research of the following resources will be conducted to supplement the list of known and available technologies to be considered: Internet journal search, Dialogue databases, Transportation Research Service, several transportation agencies (i.e., WSDOT, ODOT, and Caltrans), EPA, and Ecology.

- Consult with vendors. Up to four vendors of specific source reduction and/or treatment technologies will be consulted to gather additional product information.

- Prepare and submit list. A technical memorandum listing known and available technologies will be submitted to STATE, who will transmit it to other stakeholders (i.e., Ecology, WDFW, USFW, and NMFS) for concurrence.

  - Screen Technologies. The technology list will be screened to eliminate technically infeasible options, including those infeasible because of design constraints documented by STATE. Criteria for screening out the infeasible options will be based primarily on the following: technical unfeasibility; degree of commercialization; reliability, maintainability; availability of the technology; availability of performance and cost data; performance in removing pollutants of concern; and excessive cost. To simplify the remaining detailed analysis, the remaining technologies following the initial screening may be further grouped based on similar cost and performance. A meeting will be held with the agency stakeholders to discuss the unscreened list and screened technologies. This meeting will be combined with a field trip to the I-90 and Hood Canal floating bridges to see the design/treatment limitations of floating bridges. A final list of the surviving technologies will be prepared. The rationale for dropping technologies from the list will also be documented.

  - Evaluate Remaining Feasible Technology Options.

- Prepare interrelationship diagram. In many cases, technologies can be combined to achieve good performance results at a reasonable cost. A diagram illustrating the interrelationships of feasible technologies will be prepared.

- Develop alternatives. Using the interrelationship diagram, alternatives will be identified, including discrete and/or combinations of technologies.

- Perform cost-effectiveness analysis. The developed alternatives will be analyzed using available cost data and published removal data. Assumptions and limitations of the analysis will be documented.

- Rank alternatives. The alternatives will be ranked based on reasonableness criteria (i.e., cost effectiveness and using measures such as cost per pound of target pollutant removed).

  - Document Selected Alternative(s) and Prepare STATE Review Draft AKART Report. A discussion of selected alternative(s) and draft conclusions will be prepared. A draft AKART Report will be prepared for STATE and Sound Transit review that will incorporate findings and conclusions from previous tasks.

  - Meet with STATE and Prepare Agency Review AKART Report. A meeting will be held with STATE to discuss the findings. Following receipt of consolidated STATE comments, an agency review draft AKART Report will be prepared addressing STATE comments in the report.

  - Meet with Resource Agencies and Final AKART Report. A meeting will be held with Ecology and other regulatory agencies to discuss the AKART and water quality report findings. Following receipt of agency comments, a meeting will be held with STATE to review agency comments. A final AKART report will be prepared, addressing agency comments in the report and in a separate responsiveness summary memo. This scope of work assumes that 24 hours will be required to address agency comments.

Water Quality Report: The following tasks define the work activities that will be performed to prepare the Water Quality Report, and to communicate the approach and findings.

- Collect and Summarize Relevant Stormwater and Lake Water Quality Data.

- Data searches will be conducted of the following resources to develop the database of relevant background Lake Washington water quality data: King County DNR (Water and Land Resources Division), University of Washington libraries, Ecology, and EPA.

- Relevant data will be reviewed and screened to assess the data quality. Data quality limitations will be identified based on information available from the references and data source.

- An annotated bibliography of the database of relevant bridge stormwater runoff data and background Lake Washington water quality data will be prepared.

- A technical memorandum listing known, available, and relevant stormwater runoff data and water quality data will be submitted to STATE for review by other stakeholders (i.e., WSDOT, Ecology, WDFW, USFW, and NMFS) for concurrence. If necessary, a teleconference meeting will be held with the agency stakeholders to discuss the list. Following the meeting, the memorandum will be finalized.

- Perform Dilution Modeling of Potential Bridge Stormwater Discharges. Stormwater discharge designs for the three floating bridge alternatives, provided by STATE, will be the basis for modeling. Estimates of point source discharge loads will be developed based on available data and the FHWA protocols for highway runoff. Point source dilution modeling will be conducted to represent the dilution or mixing predicted at 10 feet and 100 feet from a discharge point. Modeling will be conducted using the appropriate model (e.g., CORMIX3, UDKHDEN, PDS, or RIVPLUM5). Overlap of adjacent stormwater discharges will be addressed (as necessary). Dilution modeling will be developed for three runoff scenarios—the low volume storm, mean annual storm, and the water quality treatment storm.

If the results of the dilution modeling and the subsequent evaluation of water quality compliance demonstrate that the stormwater runoff concentrations would exceed state water quality standards at 10 feet and 100 feet from discharge points, then the stormwater discharge designs would need to be modified with STATE. Modeling and evaluation of modified stormwater discharge designs is not included in this scope of work.

- Evaluate Water Quality Standards Compliance. Results of the dilution modeling analyses and the database of relevant bridge stormwater runoff data and background Lake

Washington water quality data will be used to evaluate whether the untreated stormwater runoff will meet state water quality standards. The untreated stormwater runoff data will be evaluated for the three bridge alternatives. The untreated stormwater runoff data will then be reduced based on the treatment option proposed in the AKART analyses, and evaluated for compliance with state water quality standards. This water quality evaluation will estimate runoff values that represent dry season first-flush, wet season first-flush, and wet season average conditions. Analyses will be limited to those parameters that FHWA lists as constituents of highway runoff. Projected discharge concentrations will be compared with acute and chronic chemical criteria defined in the state water quality standards to provide a screening evaluation of protection of aquatic species (including salmonids) beyond the mixing zone boundaries. If the results of the dilution modeling and the subsequent evaluation of water quality compliance demonstrate that the stormwater runoff concentrations would exceed acute and chronic chemical criteria for the protection of aquatic life at the mixing zone boundaries, then additional evaluations of impacts to aquatic species may be appropriate. Additional evaluations of impacts to aquatic species are not included in this scope of work.

- Develop STATE Review Draft Water Quality Report. Results of the data development, dilution modeling, and the evaluation of water quality standards compliance will be summarized in a draft report. The report will include draft study conclusions. A Draft Water Quality Report will be submitted to STATE and Sound Transit for review.

- Meet with STATE and Prepare an Agency Review Water Quality Report. A meeting will be held with STATE to discuss the findings presented in the report and their review comments. Following receipt of consolidated STATE comments, an agency review draft Water Quality Report will be prepared, addressing STATE comments in the report.

- Meet with Resource Agencies, and Final Water Quality Report. A meeting will be held with Ecology and other regulatory agencies to discuss and review the findings of the Water Quality Report (this meeting is the same meeting listed earlier for discussion of final AKART report). Following receipt of agency comments, a meeting will be held with STATE to review agency comments. A final Water Quality Report will be prepared to address agency comments, and a separate responsiveness summary memo will identify the comments and responses. This scope of work assumes that 24 hours will be required to address agency comments.

Products: AKART Technologies Summary Technical Memorandum

- STATE Review Draft AKART Report

- Agency Review Draft AKART Report

- Final AKART Report

- Responsiveness Summary Technical Memorandum for Agency Comments on Draft AKART Report

- Water Quality Data Sources Technical Memorandum
- STATE Review Draft Water Quality Report
- Agency Review Draft Water Quality Report
- Final Water Quality Report
- Responsiveness Summary Technical Memorandum for Agency Comments on Draft Water Quality Report

APPENDIX B

Bridge Drawings

To be provided

APPENDIX C

Hydrology

Table C-1
Bridge Assumptions

All Alternatives	
High rise (high point)/start of west end transition	113+75
End of west end transition/start of level bridge	131+42
End of level bridge/start of east end transition	163+00
End of east end transition/start of fixed structure	185+07
End of east end of bridge/start of land based alignment	193+45
Length of bridge analysis	7132 ft
Length of pontoon plus cross pontoon	420 ft
Draft of pontoon	14 ft
Average Event Mean Concentration (EMC), Cm	6 ft
4-Lane Alternative	
Width Of Roadway Eastbound	38 ft
Width Of Roadway Westbound	38 ft
Spacing between catch basins	180 ft
	80 cbs
6-Lane Alternative	
Width of roadway eastbound	60 ft
Width of roadway westbound	60 ft
Spacing between catch basins	120 ft
	34 vaults
	120 cbs
8-Lane Alternative	
Width of roadway eastbound	72 ft
Width of roadway westbound	72 ft
Spacing between catch basins	60 ft
	238 cbs

Abbreviations:
cbs = catch basin
ft = feet

Table C-2
Western Washington Ecology Manual SCS Curve Number Method Results

	Impervious Area (ac)	P (in)	CN	S	Qd (in)	Volume (cf)
4-Lane Alternative (per vault)						
WQ treatment design volume	0.366	1.30	98	0.204	1.080	1434.4
50% WQ Treatment Storm	0.366					717.2
10% WQ Treatment Storm	0.366					143.4
2-yr return period	0.366	1.80	98	0.204	1.576	2094.3
10-yr return period	0.366	2.70	98	0.204	2.470	3281.1
25-yr return period	0.366	3.15	98	0.204	2.918	3876.4
100-yr return period	0.366	3.85	98	0.204	3.615	4803.5
6-Lane Alternative (per vault)						
WQ treatment design volume	0.579	1.30	98	0.204	1.080	2269.2
50% WQ Treatment Storm	0.579					1134.6
10% WQ Treatment Storm	0.579					226.9
2-yr return period	0.579	1.80	98	0.204	1.576	3313.1
10-yr return period	0.579	2.70	98	0.204	2.470	5190.6
25-yr return period	0.579	3.15	98	0.204	2.918	6132.3
100-yr return period	0.579	3.85	98	0.204	3.615	7598.9
8-Lane Alternative (per vault)						
WQ treatment design volume	0.579	1.30	98	0.204	1.080	2269.2
50% WQ Treatment Storm	0.579					1134.6
10% WQ Treatment Storm	0.579					226.9
2-yr return period	0.579	1.80	98	0.204	1.576	3313.1
10-yr return period	0.579	2.70	98	0.204	2.470	5190.6
25-yr return period	0.579	3.15	98	0.204	2.918	6132.3
100-yr return period	0.579	3.85	98	0.204	3.615	7598.9

Notes:

S = (1000/CN) -10

Qd (in) = (P-0.2S)^2/(P+0.8S)   for P>=0.2S

Qd (in) = 0   for P<0.2S

V = Qd (in) * A (ac) * 3630 cu. ft./ac.-in.

Precipitation for 6-month, 24 hour storm is 72% of 2-year, 24-hour precipitation

Abbreviation:

A = area
ac = acre
ac.in. = acre-inch
CN = curve number
cu. ft. = cubic feet
P = precipitation
Qd = runoff
S = potential maximum retention after runoff
V = volume
WQ = water quality
y = year

Table C-3
Assumptions for Flow Rate Calculations

Bridge assumptions	
Total length of deck on floating bridge	7560 ft
Length of bridge section	420 ft
4-Lane Alternative	
Average event mean concentration (emc), cm	38 ft
Width of roadway westbound	38 ft
Spacing between catch basins	180 ft
Total no. of catch basins	84 catch basins
Total no. of vaults	36 vaults
6-Lane Alternative	
Width of roadway eastbound	60 ft
Width of roadway westbound	60 ft
Spacing between catch basins	120 ft
Total no. Of catch basins	126 catch basins
Total no. of vaults	36 vaults
8-Lane Alternative	
Width of roadway eastbound	72 ft
Width of roadway westbound	72 ft
Spacing between catch basins	60 ft
Total no. of catch basins	252 catch basins
Total no. of vaults	36 vaults
Hydrology Assumptions	
• WWHM v1.25e	
• King County Map Locator	
• Non-standard/commercial development	
• Ratio of 91% flow rate to 2-year frequency vs. Effective Impervious Area (Table 4-1, WW Ecology Manual)	
• 1-hour time step = 0.32	
• 15-min time step = 0.43	

Source: KCRTS v4.4, King County Runoff Time Series, 15-min time step

Table C-4
Results of WWHM Methodology Using KCRTS 2-year flow (15-Minute Time Step)

	Impervious Acres (ac)	2-yr Frequency Flow (cfs)	Water Quality treatment flow (cfs)	50% Water Quality Treatment Storm (cfs)	10% Water Quality Treatment Storm (cfs)
4-Lane Alternative					
Flow per vault	0.366	0.174	0.075	0.037	0.007
Flow per catch basin	0.157	0.075	0.032	0.016	0.003
6-Lane Alternative					
Flow per vault	0.579	0.276	0.119	0.059	0.012
Flow per catch basin	0.165	0.078	0.034	0.017	0.003
8-Lane Alternative					
Flow per vault	0.694	0.331	0.142	0.071	0.014
Flow per catch basin	0.099	0.047	0.020	0.010	0.002

APPENDIX D

Literature Search, Screening Memorandum, and Screening Matrix

Trans-Lake Washington Project
Washington State Department of Transportation
Sound Transit

TECHNICAL MEMORANDUM

Date: **September 16, 2002**

To: **Les Rubstello/WSDOT**
Paul Krueger/WSDOT

From: **Guy Caley/CH2M HILL**
Tawni Hoang/CH2M HILL
Jim Mavis/CH2M HILL

Subject: **AKART Study**
Literature Search and Draft Unscreened Water Quality Treatment Technology List

cc: **Dave Hilderbrant/Parametrix**
Jeff Peacock/Parametrix
Steve Kennedy/Sound Transit

E-File ID:

Filing Code: **08040504**

As a first order of work for the AKART Study task, we conducted a literature search of methods, technologies, and other topics related to water quality treatment options for the State Route 520 (SR 520) floating bridge. Based on the literature search, we prepared a list of specific methods and technologies to be screened for further evaluation (see Table 1).

Technical publications and vendor information relating to highway runoff/treatment (specifically for bridges, when available) were searched, listed, and then evaluated for their relevance to the SR 520 project. The focus of the literature search was limited to data sources from the past 10 years (since 1992); these data sources are listed below. Table 1 (attached) lists the specific water quality treatment technologies for further evaluation.

- Commercial databases available through DIALOG Corporation:

  Ei Compendex* for engineering literature

  Pollution Abstracts* for environmental/water pollution literature

  Enviroline for environmental/water pollution literature

  Water Resources Abstracts* for environmental/water pollution literature

NTIS (National Technical Information Service) and GPO Monthly Catalog for government and technical reports.

- Bibliographic Internet databases:

  TRIS Online, a database of transportation literature developed by the Transportation Research Board

  ASCE Civil Engineering Database, a database of all ASCE publications since 1972.

- Government agency web sites including:

  U.S. Environmental Protection Agency National Stormwater Best Management Practices Database

  Washington State Department of Ecology

  Washington State Department of Transportation

  California Department of Transportation (Caltrans)

  Maryland Department of Transportation

  Maryland Department of the Environment, Stormwater Management Program

  Chesapeake Bay Program, Innovative Technology Clearinghouse

  City of Los Angeles Stormwater Management Division

  Santa Monica Cities Consortium, Municipal Stormwater Urban Runoff Pilot Project.

- Online library catalogs of various universities and agencies:

  Washington State Department of Transportation Library

  University of Washington Libraries

  MELVYL (the University of California library system)

  Northwestern University Transportation Library

  National Transportation Library

  British Library.*

- Vendor publications and data of specific technologies.

Note that an asterisk indicates an international data source

Please review these sources of information and the list of technologies in Table 1. If there are additional information references or technologies that should be included in this list, please reference them for a final list. The final list of technologies will then be screened to eliminate the infeasible and design-constrained options, leaving the technologies for further evaluation.

To facilitate the project schedule, please provide review and feedback by September 19. If you have any questions about this request, please contact Guy Caley at 425-233-3567.

Attachment

Trans-Lake Washington Project
Washington State Department of Transportation
Sound Transit

TECHNICAL MEMORANDUM

Date: **October 9, 2002**

To: **Les Rubstello/WSDOT**
Paul Krueger/WSDOT

From: **Guy Caley/CH2M HILL**
Tawni Hoang/CH2M HILL
Jim Mavis/CH2M HILL

Subject: **SR 520 Floating Bridge**
AKART Study-Initial Technology Screening

cc: **Dave Hilderbrant/Parametrix**
Jeff Peacock/Parametrix
Steve Kennedy/Sound Transit

E-File ID:

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This memorandum documents the initial screening portion of the AKART report, which examines options for treating stormwater on the SR 520 floating bridge. The proposed bridge presents unique design constraints when considering appropriate stormwater treatment options. The intent of the screening effort is to use initial information about the known treatment options to eliminate those that are considered infeasible or "fatally flawed" due to these constraints.

Screening Methodology

An 8-hour screening workshop was conducted on September 24, 2002, at the Trans-Lake Washington Project Office. Participating in the screening process was an interdisciplinary team of WSDOT and consultant staff, representing the areas of environmental/water quality, bridge design, bridge maintenance, stormwater design, and project management.

The list of known and available technologies used in the screening was developed from a literature and vendor search, and reviewed by stakeholders. Technologies were grouped into appropriate treatment categories for screening based on function. This allowed efficient evaluation of groups of specific technologies that perform similarly and/or have similar limitations. Treatment categories screened were gravity separation, swirl concentration, media filtration in vaults, biofiltration, catch basin media filtration with pillows or cartridges, catch basin filtration with screens or filter bags, chemical coagulation, electrical coagulation, high-efficiency sweeping, modified catch basins/cleaning, pump/conveyance systems, separate floating structures, covered roadway, wheelwash stations, and mechanical filtration.

A list of criteria to evaluate the feasibility of each treatment category was then established. These criteria took the form of questions that covered the areas of engineering, maintenance, safety, environment, and cost. The screening questions were applied to each treatment category to assess if it was a candidate for further evaluation in the AKART, or was infeasible for use on the floating bridge (fatally flawed). A category was considered to be infeasible/fatally flawed if negative response(s) to the questions indicated that implementation on the bridge would be unsuccessful or would involve unacceptable risk or unreasonable requirements to install and maintain the technology. The first four questions were initially addressed for fatal flaw responses (Screening Phase 1). These questions were deemed most critical to meet immediate and long-term water quality treatment goals on the bridge. If the treatment category was not considered flawed based on these initial questions, the remaining questions were then answered for the category (Screening Phase 2).

The team discussed, derived, and validated the following screening questions:

Screening Phase 1 Questions

- Does it remove highway pollutants of concern (TSS, oil/grease, metals)
- Is it functional during bridge movement, vibration, and wave action? (Does this technology function in the bridge environment?)
- Is it commercially available and does it have long-term availability? (Assurance that the technology is available now and in the future)
- Is the installation or its parts proprietary? (Assurance that the technology can be properly maintained in the future without reliance on potentially unavailable parts)

Screening Phase 2 Questions

- Are there other potential ecosystem impacts? (Consideration of additional impacts to land and air)
- Is the performance data available? (Although no data are available for treatment on floating bridges.)
- How safe is it to maintain on the bridge? (Low, Medium, High)
- How accessible and reasonable is it to maintain? (Low, Medium, High)
- Is it dependent on automated mechanical and electrical systems?
- Is it reliable long-term? (Can it hold up to the bridge environment?)
- Degree of risk of flooding roadway? (Low, Medium, High)
- Degree of risk of flooding pontoons? (Low, Medium, High)
- Is it structurally feasible? (Compatible with the bridge design?)

- Are there special cost considerations?
- Are there other potential adverse impacts (i.e., noise, aesthetics)?
- Are there compatibility issues with spill control systems?

The attached matrix was developed and contains the collective responses of the team. The following discussion summarizes each screened treatment category.

Infeasible Categories

The following treatment categories were considered to be infeasible for use on the floating bridge and will be dropped from further consideration. Several treatment categories were screened out in Phase 1 due to fatal flaw responses (Swirl Concentration, Chemical Coagulation, Electrical Coagulation, and Separate Floating Structure). Brief discussions and justification are presented for all screened categories.

Gravity Separation

This treatment category is designed to retain the treatment storm volume in a vault that allows gravity settlement of suspended solids. For a 6-lane bridge, the stored water volume on a typical pontoon is estimated to be 5,200 ft^3. WSDOT has experienced dynamic response problems on the existing SR 520 bridge when these water volumes were maintained in the ballast cells. Placement of large, gravity separation tanks on the bridge pontoons would create similar load problems and affect the structural integrity of the bridge.

In addition, this method is considered to be ineffective on the floating bridge from a performance perspective. Under normal traffic loading, the pontoons are expected to move with wind and wave action. Since this category of treatment requires tranquil, laminar flow, the expected, multi-directional bridge movements would prevent effective settlement of solids.

For these reasons, technologies using large water volumes for gravity separation as a treatment process were deemed an infeasible option for use on the floating bridge.

Swirl Concentration

Treatment devices in this category remove pollutants from stormwater by vorticity (circular motion) and gravity settling with laminar flow, and hence require stationary units. The vortex motion of the stormwater hydraulics required in these units would be interrupted during the bridge motion described above and would prevent settlement of pollutants. These devices are also proprietary and would require dependence on a single manufacturer for long-term maintenance. For these reasons, this treatment category is considered infeasible.

Biofiltration

Biofiltration requires vegetation and biological contact with stormwater to treat stormwater pollutants. Vegetation on the bridge could not be properly installed and maintained, and would not survive on the bridge. Plant growth also risks damaging the structure of the bridge by plant root intrusion. Plant viability under shaded pontoons, wave action, and during dry seasons would prevent its success on the bridge. For these reasons, coupled with excessive capital investment cost and long-term maintenance problems, biofiltration as a treatment category was deemed infeasible for use on the floating bridge.

Chemical Coagulation

This treatment category uses a chemical coagulant applied to settleable solids using storage tanks. Chemical coagulation also requires subsequent gravity separation of coagulated particles. Gravity settlement has been discussed as an infeasible option for use on a vibrating, moving bridge (see *Gravity Separation*). For pollutant removal, chemical coagulation also requires a waste solids recovery and disposal method, which would involve complex mechanical and electrical systems. In addition, coagulants have not been approved for direct discharge to receiving waters. For these reasons, this treatment category was deemed an infeasible option.

Electrical Coagulation

Similar to chemical coagulation, this treatment category uses gravity separation for settlement of coagulated particles. Gravity settlement has been discussed as an infeasible option for use on a vibrating, moving bridge (see *Gravity Separation*). For pollutant removal, electrical coagulation also requires a waste solids recovery and disposal method. This would involve complex mechanical and electrical systems. For these reasons, this treatment category was deemed infeasible.

Pump/Conveyance System

This option involves constructing and maintaining a pipe network to convey stormwater off the bridge to treat flows elsewhere. Based on WSDOT experience with pump and conveyance systems on the I-90 and Hood Canal floating bridges, this approach is excessive and unreliable, and involves an unacceptable level of risk. For example, the runoff from a 2-year storm on a 6-lane SR 520 bridge of this length would require approximately 154 97-gpm pumps, each powered by a 5.5 horsepower motor. In the event of a power and pump system failure, provisions would have to be made for allowing runoff water to spill off the bridge. The Lacey V. Murrow Bridge had a pumping system to control ballast water and this system was plagued with pump and piping failures that led to decommissioning of the system. Due to its unreliability, this treatment category was deemed an infeasible option.

Separate Floating Structure

This technology involves constructing separate pontoons, barges, or other floating structures adjacent to the proposed bridge to support the treatment method. This would require pumping stormwater from the bridge across or under the water (another infeasible option), and constructing and maintaining additional engineered elements such as ballast, monitoring systems, and anchors. Anchors would conflict with the bridge anchors. All components of the floating structure would require individual design, construction, and inspection. This technology would require access from a custom boat and the transfer of materials and pollutants to and from shore. For these reasons, a separate floating structure as a treatment option was deemed infeasible for use on the floating bridge.

Covered Roadway

Enclosing the roadway surface was considered. By protecting the bridge from wet weather flows, pollutants of concern would remain on the bridge deck. This would require extensive ventilation, lighting, and security systems, as well as additional buoyancy in the bridge pontoons, thereby introducing larger structural elements and excessive cost. For these reasons, a covered roadway was deemed infeasible on the floating bridge.

Wheelwash Stations

This treatment method involves stopping vehicles and removing sediments with pressurized water. Wheelwash stations could reduce total suspended solids, but would do little to remove oil and grease from the bridge deck. Additionally, this treatment category would require separate land-based treatment of pollutants. With a high risk of roadway flooding, high maintenance, and the expected traffic delays, the team deemed this treatment option infeasible for the floating bridge.

Mechanical Filtration

Stormwater treatment using this proprietary technology has had limited application. These systems are complex to construct, operate and maintain. Due to their dependence on mechanical and electrical systems such as multiple booster pumps, the nature of the target contaminants, and excessive maintenance demands, this treatment category was deemed infeasible for use on the floating bridge.

Potentially Feasible Treatment Catagories

Based on the initial screening process, these treatment categories are considered potentially feasible and will be further examined in the AKART report.

Media Filtration – Vaults

This treatment category involves filtering stormwater through media beds or cartridges. Although this treatment category was not initially seen as infeasible by the screening team, some considerations for advanced screening will be required. These include the proprietary nature of the media, the difficulty in maintenance/accessibility of vaults on the pontoons, and initial capital and long-term maintenance costs.

Catch Basin Media Filtration – Pillows/Cartridges

This treatment category involves filtration of pollutants in individual catch basins on the bridge deck. Some of these proprietary technologies are sold with filter cartridges and others with media pillows. Some considerations for additional screening include maintenance and safety concerns along the highway shoulder, risk of roadway flooding due to media clogging, and initial capital and long-term maintenance costs.

Catch Basin Filtration – Screen/Filter Bags

This treatment category involves filtration of pollutants in individual catch basins on the bridge deck with screens or geotextile filter bags. The considerations for additional screening are similar as above.

High-Efficiency sweeping

This treatment category involves removing pollutants from the roadway surface with advanced roadway sweeping methods such as vacuuming and regenerative air. This prevents pollutants from entering the bridge drainage system instead of treating collected pollutants. Some considerations for additional screening include the sweeping frequency to remove pollutants of concern to target levels, removal efficiency rates, and long-term operation and maintenance costs.

Modified Catch Basins/Cleaning

This treatment category consists of trapping pollutants in larger than standard catch basins along the bridge deck with modified elements such as sumps and outlets elbows. Frequency of cleaning and maintenance are important to prevent the basins from filling and keeping pipes clear.

Conclusion

The initial screening of the 15 technology categories identified 10 that were considered infeasible for use on the SR 520 floating bridge, which will not be further considered. The five remaining categories will be further evaluated for a selected alternative in the AKART report.

Attachment: Screening Matrix

APPENDIX E

BMP Performance and Cost Data

Table E-1
Multiple BMP Pollutant Removal Calculations

Pollutant	Alternative	Initial Pollutant Load (lbs/yr)	BMP 1 (% removal)	Intermediate Pollutant Load (lbs/yr)	BMP 2 (% removal)	Intermediate Pollutant Load (lbs/yr)	BMP 3 (% removal)	Final Pollutant Load (lbs/yr)	Pounds of Pollutants Removed (lbs/yr)	Composite Removal Efficiency (%)
TSS	Alt 1 range low	13,539	17%	11,237	39%	6,844	63%	2,532	11,007	81%
	Alt 1 range high	13,539	72%	3,791	75%	948	84%	152	13,387	99%
	Alt 2 range low	13,539	17%	11,237	39%	6,844	63%	2,532	11,007	81%
	Alt 2 range high	13,539	72%	3,791	75%	948	84%	152	13,387	99%
	Alt 3 range low	13,539	17%	11,237	39%	6,844	0%	6,844	6,695	49%
	Alt 3 range high	13,539	72%	3,791	75%	948	0%	948	12,591	93%
	Alt 4 range low	13,539	50%	6,769	39%	4,123	0%	4,123	9,416	70%
	Alt 4 range high	13,539	77%	3,114	75%	778	0%	778	12,760	94%
Oil and Grease	Alt 1 range low	1,358	14%	1,168	13%	1,016	28%	732	627	46%
	Alt 1 range high	1,358	61%	530	26%	392	64%	141	1,217	90%
	Alt 2 range low	1,358	14%	1,168	13%	1,016	28%	732	627	46%
	Alt 2 range high	1,358	61%	530	26%	392	64%	141	1,217	90%
	Alt 3 range low	1,358	14%	1,168	13%	1,016	0%	1,016	342	25%
	Alt 3 range high	1358	61%	530	26%	392	0%	392	966	71%
	Alt 4 range low	1,358	20%	1,087	13%	945	0%	945	413	30%
	Alt 4 range high	1,358	80%	272	26%	201	0%	201	1,157	85%
Cadmium	Alt 1 range low	0.7	7%	0.7	17%	0.6	29%	0.4	0.3	45%
	Alt 1 range high	0.7	31%	0.5	32%	0.3	78%	0.1	0.6	90%
	Alt 2 range low	0.7	7%	0.7	17%	0.6	29%	0.4	0.3	45%
	Alt 2 range high	0.7	31%	0.5	32%	0.3	78%	0.1	0.6	90%

Table E-1
Multiple BMP Pollutant Removal Calculations

Pollutant	Alternative	Initial Pollutant Load (lbs/yr)	BMP 1 (% removal)	Intermediate Pollutant Load (lbs/yr)	BMP 2 (% removal)	Intermediate Pollutant Load (lbs/yr)	BMP 3 (% removal)	Final Pollutant Load (lbs/yr)	Pounds of Pollutants Removed (lbs/yr)	Composite Removal Efficiency (%)
Cadmium (cont'd.)	Alt 3 range low	0.7	7%	0.7	17%	0.6	0%	0.6	0.2	23%
	Alt 3 range high	0.7	31%	0.5	32%	0.3	0%	0.3	0.4	53%
	Alt 4 range low	0.7	46%	0.4	17%	0.3	0%	0.3	0.4	55%
	Alt 4 range high	0.7	59%	0.3	32%	0.2	0%	0.2	0.5	72%
Copper	Alt 1 range low	3.2	8%	2.9	19%	2.4	25%	1.8	1.4	44%
	Alt 1 range high	3.2	35%	2.1	37%	1.3	96%	0.1	3.1	98%
	Alt 2 range low	3.2	8%	2.9	19%	2.4	25%	1.8	1.4	44%
	Alt 2 range high	3.2	35%	2.1	37%	1.3	96%	0.1	3.1	98%
	Alt 3 range low	3.2	8%	2.9	19%	2.4	0%	2.4	0.8	25%
	Alt 3 range high	3.2	35%	2.1	37%	1.3	0%	1.3	1.9	59%
	Alt 4 range low	3.2	34%	2.1	19%	1.7	0%	1.7	1.5	47%
	Alt 4 range high	3.2	53%	1.5	37%	0.9	0%	0.9	2.3	70%
Lead	Alt 1 range low	3.1	15%	2.7	33%	1.8	29%	1.3	1.9	60%
	Alt 1 range high	3.1	61%	1.2	64%	0.4	78%	0.1	3.0	97%
	Alt 2 range low	3.1	15%	2.7	33%	1.8	29%	1.3	1.9	60%
	Alt 2 range high	3.1	61%	1.2	64%	0.4	78%	0.1	3.0	97%
	Alt 3 range low	3.1	15%	2.7	33%	1.8	0%	1.8	1.4	43%
	Alt 3 range high	3.1	61%	1.2	64%	0.4	0%	0.4	2.7	86%
	Alt 4 range low	3.1	46%	1.7	33%	1.1	0%	1.1	2.0	64%
	Alt 4 range high	3.1	59%	1.3	64%	0.5	0%	0.5	2.7	85%

Table E-1
Multiple BMP Pollutant Removal Calculations

Pollutant	Alternative	Initial Pollutant Load (lbs/yr)	BMP 1 (% removal)	Intermediate Pollutant Load (lbs/yr)	BMP 2 (% removal)	Intermediate Pollutant Load (lbs/yr)	BMP 3 (% removal)	Final Pollutant Load (lbs/yr)	Pounds of Pollutants Removed (lbs/yr)	Composite Removal Efficiency (%)
Zinc	Alt 1 range low	18.6	9%	16.9	21%	13.4	15%	11.4	7.2	39%
	Alt 1 range high	18.6	39%	11.4	41%	6.7	91%	0.6	18.0	97%
	Alt 2 range low	18.6	9%	16.9	21%	13.4	15%	11.4	7.2	39%
	Alt 2 range high	18.6	39%	11.4	41%	6.7	91%	0.6	18.0	97%
	Alt 3 range low	18.6	9%	16.9	21%	13.4	0%	13.4	5.2	28%
	Alt 3 range high	18.6	39%	11.4	41%	6.7	0%	6.7	11.9	64%
	Alt 4 range low	18.6	31%	12.8	21%	10.1	0%	10.1	8.5	45%
	Alt 4 range high	18.6	49%	9.5	41%	5.6	0%	5.6	13.0	70%

Notes:

Alternative 1: Conventional Sweeping (BMP 1) + Modified Catch Basin/Cleaning (BMP 2) + Media Filtration Vault (BMP 3)
Alternative 2: Conventional Sweeping (BMP 1) + Catch Basin Filtration (BMP 2)
Alternative 3: Conventional Sweeping (BMP 1) + Modified Catch Basin/Cleaning (BMP 2)
Alternative 4: High-Efficiency sweeping (BMP 1) + Modified Catch Basin/Cleaning (BMP 2)

Sources:

Initial Pollutant Loadings

Kayhanian M., L.Hollingsworth, M. Spongberg, L. Regenmorter, and K. Tsay. January 2002. Characteristics of Stormwater Runoff from CalTrans Facilities. Transportation Research Board, Annual Conference, Washington D.C. Table 3.

FHWA (Federal Highway Administration). March 1985. Effects of Highway Runoff on Receiving Waters , Vol. III, Resource Document for Environmental Assessments. Publication FHWA/RD-84/064. Table 1. Summary of highway runoff quality data for six monitoring sites and typical urban runoff quality based on data from 28 cities: average pollutant concentration. McLean, Virginia.

Conventional Sweeping

FHWA (Federal Highway Administration). May 1984. Sources and Migration of Highway Runoff Pollutants Volume III: Research Report. Publication No. FHWA/RD-84/059.

Kayhanian M., L.Hollingsworth, M. Spongberg, L. Regenmorter, and K. Tsay. January 2002. Characteristics of Stormwater Runoff from CalTrans Facilities. Transportation Research Board, Annual Conference, Washington D.C. Table 3.

Modified Catch Basin

EPA (United States Environmental Protection Agency). May 1977. Catchbasin Technology Overview and Assessment. Publication EPA-600/2-77-051. EPA Municipal Environmental Research Laboratory, Office of Research and Development. Cincinnati, Ohio. Prepared by Metcalf and Eddy, Inc., Palo Alto, California. p. 84.

FHWA (Federal Highway Administration). April 1990. Pollutant Loadings and Impacts from Highway Stormwater Runoff. Volume I: Design Procedure. Publication No. FHWA-RD-88-006. p. 15.

Kayhanian M., L.Hollingsworth, M. Spongberg, L. Regenmorter, and K. Tsay. January 2002. Characteristics of Stormwater Runoff from CalTrans Facilities. Transportation Research Board, Annual Conference, Washington D.C. Table 3.

Table E-1
Multiple BMP Pollutant Removal Calculations

Notes (continued):

Media Filtration

SMI. 2000. Total Suspended Solids Removal Using StormFilter Technology. Portland, OR.

CalTrans (California Department of Transportation). 2002. BMP Retrofit Pilot Program. Report CTSW-RT-01-050. Sacramento, CA. April 2002.

SMI. 2000. Oil, Grease, and Hydrocarbon Removal Using StormFilter Technology. Portland, OR.

High-Efficiency Sweeping

Sutherland, R.C. , and S.L. Jelen. 1997. "Contrary to Conventional Wisdom, Street Sweeping Can be an Effective BMP," Advances in Modeling the Management of Stormwater Impacts, Vol. 5. Ed., W. James. Computational Hydraulics International. Guelph, Ontario. pp. 179-190.

Sutherland, R.C., S.L. Jelen, and G. Minton. 1998. High Efficiency Sweeping as an Alternative to the Use of Wet Vaults for Stormwater Treatment. Advances in Modeling the Management of Stormwater Impacts - Vol 6. W. James, Ed. Pub. By CHI, Guelph, Canada 1998. ISBN 0-9697422-8-2. pp. 369-370.

Table E-2
Alternative 4[a]—Comparison of Maintenance Frequency Using Multiple BMP Pollutant Removal

Sweeping Frequency	Catch Basin Cleaning Frequency	Initial Pollutant Load[b] (lbs)	BMP 1[c] (% Removal)	Intermediate Pollutant Load (lbs)	BMP 2[d] (% Removal)	Final Pollutant Load (lbs)	Pounds of Pollutant Removed (lbs/yr)	Final Removal Efficiency (%)
TSS								
Weekly	Annual	13,539	77%	3,114.0	39.1%	1,896.4	11,642.6	86%
Bi-Monthly	Annual	13,539	60%	5,415.6	39.1%	3,298.1	10,240.9	76%
Monthly	Annual	13,539	50%	6,769.5	39.1%	4,122.6	9,416.3	70%
Weekly	Bi-Annual	13,539	77%	3,114.0	75%	778.5	1,2760.5	94%
Bi-monthly	Bi-Annual	13,539	60%	5,415.6	75%	1,353.9	1,2185.1	90%
Monthly	Bi-Annual	13,539	50%	6,769.5	75%	1,692.4	1,1846.6	88%
Cadmium								
Weekly	Annual	0.7	59%	0.3	39.1%	0.2	0.5	75%
Bi-monthly	Annual	0.7	52%	0.3	39.1%	0.2	0.5	71%
Monthly	Annual	0.7	46%	0.4	39.1%	0.2	0.5	67%
Weekly	Bi-Annual	0.7	59%	0.3	75.0%	0.1	0.6	90%
Bi-monthly	Bi-Annual	0.7	52%	0.3	75.0%	0.1	0.6	88%
Monthly	Bi-Annual	0.7	46%	0.4	75.0%	0.1	0.6	87%
Copper								
Weekly	Annual	3.2	53%	1.5	39.1%	0.9	2.3	71%
Bi-monthly	Annual	3.2	42%	1.9	39.1%	1.1	2.1	65%
Monthly	Annual	3.2	34%	2.1	39.1%	1.3	1.9	60%

Table E-2
Alternative 4[a]—Comparison of Maintenance Frequency Using Multiple BMP Pollutant Removal

Sweeping Frequency	Catch Basin Cleaning Frequency	Initial Pollutant Load[b] (lbs)	BMP 1[c] (% Removal)	Intermediate Pollutant Load (lbs)	BMP 2[d] (% Removal)	Final Pollutant Load (lbs)	Pounds of Pollutant Removed (lbs/yr)	Final Removal Efficiency (%)
Copper (continued)								
Weekly	Bi-Annual	3.2	53%	1.5	75.0%	0.4	2.8	88%
Bi-monthly	Bi-Annual	3.2	42%	1.9	75.0%	0.5	2.7	86%
Monthly	Bi-Annual	3.2	34%	2.1	75.0%	0.5	2.7	84%
Lead								
Weekly	Annual	3.1	59%	1.3	39.1%	0.8	2.4	75%
Bi-monthly	Annual	3.1	52%	1.5	39.1%	0.9	2.2	71%
Monthly	Annual	3.1	46%	1.7	39.1%	1.0	2.1	67%
Weekly	Bi-Annual	3.1	59%	1.3	75.0%	0.3	2.8	90%
Bi-monthly	Bi-Annual	3.1	52%	1.5	75.0%	0.4	2.8	88%
Monthly	Bi-Annual	3.1	46%	1.7	75.0%	0.4	2.7	87%
Zinc								
Weekly	Annual	18.6	49%	9.5	39.1%	5.8	12.8	69%
Bi-monthly	Annual	18.6	39%	11.4	39.1%	6.9	11.7	63%
Monthly	Annual	18.6	31%	12.8	39.1%	7.8	10.8	58%
Weekly	Bi-Annual	18.6	49%	9.5	75.0%	2.4	16.2	87%
Bi-monthly	Bi-Annual	18.6	39%	11.4	75.0%	2.8	15.8	85%
Monthly	Bi-Annual	18.6	31%	12.8	75.0%	3.2	15.4	83%

Notes:

[a] Alternative 4: High-Efficiency Sweeping (BMP 1) + Modified Catch Basin/Cleaning (BMP 2)
[b] Initial load based on drainage 6-lane alternative
[c] Source: Sutherland, R.C., and S.L. Jelen. 1997. "Contrary to Conventional Wisdom, Street Sweeping Can Be an Effective BMP," *Advances in Modeling the Management of Stormwater Impacts, Vol. 5*. Ed., W. James. Computational Hydraulics International. Guelph, Ontario. Pp. 179-190.
[d] Source: EPA. May 1997. Catchbasin Technology Overview and Assessment. EPA 600/2-77-051. PB-270 092. p. 84.

Table E-3
Cost Assumptions

	Quantity	Unit	Unit Price	Unit	Notes
Capital Cost Assumptions					
Bridge Grate Inlet Catch Basin	120	each	$4,000	each	WSDOT bridge design estimate
Vault with Media	34	each	$22,000	each	Vendor estimate
Flow Divider	34	each	$4,500	each	WSDOT bridge design estimate
Conveyance Piping	16,600	ft; 12-inch galv. steel	$120	per linear foot	WSDOT bridge design estimate
Catch Basin Cartridge Unit	120	each	$6,000	each	Vendor estimate
High-Efficiency Sweeper	1	each	$130,000	each/regenerative air	Vendor estimate, Schwartz A-series, Elgin Cross Wind
			$275,000	each/vacuum	Vendor estimate, Schwartz EV series vacuum
Mechanical Sweeper			$160,000	each/mechanical	Vendor estimate
O&M Assumptions					
Conventional Sweeping			$26,910	per year (bi-monthly)	WSDOT maintenance estimate based on experience with I-90 bridge, see Appendix
High-Efficiency Sweeping			$64,584	per year (weekly)	Assume O&M cost similar to conventional with 20% markup
			$32,292	per year (bi-monthly)	
			$16,146	per year (monthly)	
Catch Basin Cleaning			$16,200	per year (annual)	WSDOT maintenance estimate based on experience with I-90 bridge, see Appendix
			$34,400	per year (bi-annual)	
Media Vault Cartridge Replacement			$28,560		Vendor estimate, $70/cartridge, 12 cartridges/vault, 34 vaults
Catch Basin Cartridge Replacement			$25,200		Vendor estimate, $70/cartridge, 3 cartridges/catch basin, 120 catch basins

Table E-3
Cost Assumptions

	Quantity	Unit	Unit Price	Unit	Notes
Catch Basin Cartridge Maintenance			$66,440	per year	Replacements (120 catch basins, 40 minutes per catch basin, 3 hours to load/unload, 3 times per year = 250 hrs): $15,750 for tech 2, tech 3 + $1,930 for truck/crane + $9,500 for shadow truck/tech 2/attenuator Inspections (120 catch basins, 10 minutes per catch basin, 18 times per year = 360 hours): $22,680 for tech 2, tech 3 + $2,900 for truck/crane + $13,680 for shadow truck/tech 2/attenuator (truck/crane is $8 per hour; shadow truck/attenuator is $8 per hour)
			$83,050	per year	
Vault Unit Maintenance			$55,520	per year	Replacements (34 vaults, 3 hours per vault, 1 hour load/unload, 3 times per year = 309 hrs): $19,470 for tech 2, tech 3 + $10,200 for boat pilot (tech 3) Inspections (34 vaults,40 minutes per vault, 18 times per year = 410 hours): $12,300 for tech 2 + $13,550 for boat pilot (tech 3) (Labor Main. Tech 2 = $30 per hour Labor Main. Tech 3 = $33 per hour)
			$69,400	per year	

APPENDIX F

Vendor Data

To be provided

APPENDIX G

Discharge Modeling

BASIS OF THE FARFIELD DILUTION CALCULATIONS FOR DISCHARGE MODELING

Following nearfield dilution of the stormwater discharge inside of the spill containment lagoon, this stormwater/lake water mixture will be gradually discharged from the bottom of the lagoon. The lagoon water displaced or exiting the lagoon by turbulent mixing and diffusion will be rapidly diluted with the background lake water, and this is referred to as the interface region. Since the containment lagoons are long and narrow, and positioned perpendicular to the lake axis, then the predominant lake currents will transport the diluted "plume" similar to what is referred to as a "line plume" in dilution modeling. However, the line plume will be subjected to turbulent mixing at the lagoon/lake interface, and then vertical diffusion (downward) upon exiting the lagoon.

Beyond the interface region, the diluting plume will be subject to vertical mixing and diffusion. Since the plume is under the bridge pontoon for 60 to 75 feet, the only vertical mixing and plume spreading will be downward until the outer edge of the pontoon is reached. The greater the density difference between the plume and the background lake water, the greater the rate of vertical mixing. A modification of the Brooks method to include vertical diffusion has been applied. The basic relationship is first described below and then the modification to account for vertical mixing is presented.

The Brooks Method

The Brooks method specifies the intensity of lateral diffusion by application of a diffusion coefficient (Brooks, 1959; Fischer et al., 1979). This coefficient is held constant, or scaled by a length scale of the plume width, or by the 4/3 power of this length. The latter (the 4/3 power law) is generally applied to systems that are not influenced by lateral boundaries. As in any diffusion model, the specification of the diffusion coefficient is the most difficult aspect of applying the method. This coefficient can range over many orders of magnitude for different systems and environmental conditions. Since it is difficult to determine and justify an appropriate value for the coefficient, extremely conservative values are often used. The values used for this application are described in detail below.

The basic formulation of the approach results in a relationship of the form:

$$\frac{C_{MAX}}{C_0} = erf\left(\frac{1.5}{\left(1+\frac{8\cdot A\cdot t}{L^{2/3}}\right)-1}\right)^{1/2}$$

where

C_{MAX}/C_0 = the ratio of the centerline plume concentration to the initial concentration,

L = is the plume width parameter,

A = the horizontal dissipation coefficient equal to the horizontal turbulent diffusion coefficient (ε) divided by $L^{4/3}$ with dimensions of $[L]^{2/3}/[t]$,

t = the travel time of the plume from the initial line source to the point of interest,

and

erf indicates the error function.

The initial concentration is taken as a line source of arbitrary vertical dimension and uniform concentration along the source of C_0. The approach provides a prediction of the resulting centerline dilution. The flux average dilution across the plume is given by multiplying the centerline dilution by (approximately) 1.414.

The Modified Brooks Method

As discussed above, one of the well recognized limitations of the Brooks method is that only lateral dispersion is considered and the plume is assumed not to mix in the vertical direction. This is often not considered a serious limitation, since vertical diffusion may be much weaker than horizontal diffusion (typically one to two orders of magnitude) in areas of vertical confinement. However, for a plume that is much wider in the lateral direction than thicker in the vertical direction as is the case with the lagoon discharge to the lake, neglecting vertical diffusion would be incorrect. A wide plume (relative to vertical thickness), with a large surface area for vertical diffusion, may have vertical mixing processes as important as mixing in the lateral direction in terms of dilution as the plume moves along with the ambient current. This is the case for the floating bridge stormwater discharge, where a plume width many times (an order of magnitude) the plume thickness is predicted and the plume will remain submerged.

A modification of the Brooks method to include vertical diffusion was developed during an assessment of the effects of open ocean waste disposal (EPA, 1989). This formulation has been incorporated into an Excel spreadsheet application by CH2M HILL and applied to submerged plumes such as the planned floating bridge stormwater discharge. The formulation, consistent with the Brooks method, assumes a line source of constant strength. The model accounts for vertical diffusion by applying a non-dimensional concentration reduction factor based on a Fickian diffusion coefficient (K_v). The reduction factor for a surface (or bottom) plume, with one later surface available for vertical mixing, is given by a dimensionless expression of the form:

$$\frac{H/4}{\left(2 \cdot K_V \cdot t + \frac{H^2}{16}\right)^{1/2}}$$

where

H is the initial vertical plume dimension defined as the vertical extent of the plume at the starting point of the plume, and K_v is the vertical turbulent diffusivity with dimensions of $[L]^2/[t]$.

The multiplier factor is applied to the calculated centerline concentration (C_{max}) predicted by the Brooks equation to obtain an adjusted value. For a submerged plume, the factor is applied for both the top and bottom surfaces of the plume. The plume will no longer resemble a line plume, but will tend to become expanded and elliptical.

Parameter Selection

A number of parameters must be selected for the analysis. These parameters fall into two categories dependent on the plume geometry and the characteristics of the ambient receiving water. Selection of the geometric parameters is relatively straightforward. However, the selection of the diffusion coefficients to be applied, which depend on characteristics of the receiving water, and the interactions of the plume and the receiving water, are difficult to measure, often poorly understood, and highly variable. Both sets of parameters are discussed below, and the values selected for the farfield conditions are described.

Plume Geometry The parameters that depend on the plume geometry are generally easy to specify. Nearfield concentration (dilution), plume length (lateral dimension), and plume height (vertical dimension) are based on results of the nearfield interface mixing calculations. The number of horizontal surfaces involved in vertical mixing is based on whether the plume is on the surface, bottom attached, or submerged within the water column. The nearfield mixing results describe the lagoon plume trajectory and location, and therefore provides the information required (for the case considered here the plume has one horizontal surface). The distance from the end of nearfield or interface mixing dilution to the mixing zone boundary is 100 feet. The farfield calculations were done with an initial concentration specified as one (1) and farfield dilution was calculated on a relative basis as described in more detail below.

Ambient Parameters Three ambient parameters must be specified for the farfield calculation: ambient current speed, a horizontal diffusion coefficient in terms of the dissipation parameter (A), and a vertical diffusion coefficient (K_V). The ambient current speed is selected based on the range of calculated current speeds for a range of wind conditions on the lake. The ranges of reported diffusion coefficients for both lateral (horizontal diffusion of clouds) and vertical diffusion is large. The values selected are discussed below. Horizontal diffusion coefficient

(K_H) of clouds in large bodies of water is generally assumed to be proportional to the cloud (or plume) dimension (L) following the "4/3 - law", expressed functionally as:

$$K_H = A \cdot L^{4/3}$$

where A is the dissipation coefficient discussed above and used in the Brooks method. Fischer et al (1979) shows data with values of A ranging from 0.01 to 0.002 $cm^{2/3}$/sec. The calculations of farfield dilution described below use the range presented by Fischer et al. (1979). As the reasonable extremes (0.0001 to 0.0005 $m^{2/3}$/sec) with 0.0002 $m^{2/3}$/sec as the selected nominal value, which is near the low end of the range.

Vertical diffusion in a saline environment is generally much weaker than horizontal diffusion because of both scale effects and damping by density gradients, however, vertical diffusion in a lake without significant density gradients can be significant for a near surface discharge when the water depth scale is large. The diffusion coefficient K_V as a function of density gradient (ε), in the functional form:

$$K_V = B \cdot \varepsilon$$

$$\varepsilon = \frac{1}{\rho} \cdot \frac{\partial \rho}{\partial z}$$

where B is a constant (slope of the line in the figure), ρ is density, and z distance in the vertical direction. For non-stratified or extremely weak density gradients the relationship above cannot hold (an infinite value would be predicted) and an alternate specification must be used. Bowden (1967), given in Fischer et al. (1979), presents a relation of the form:

$$K_V = 0.0025 \cdot d \cdot U_A$$

where U_A is the depth averaged current speed over the depth of flow d. The approach taken in the farfield calculations presented below included an upper value of K_V of 110 cm^2/sec based on the weakly stratified formulation of Bowden and a lower value of 25 cm^2/sec based on Koh and Fan (1970). The lower value was calculated using B = 10^{-4} , which is the average value for density gradient in the lake. For the nominal case, the lower value of 25 cm^2/sec was used.

APPENDIX H

Background Data for Lake Washington

Table H-1
Background Metals in Lake Washington

	Average Value (ug/L)	Median Value (ug/L)	90th Percentile (ug/L)
Total Metals			
Mercury, Total, CVAF	0.000427	0.000425	0.000602
Cadmium, Total, ICP-MS	0.0050	0.0100	N/A
Chromium, Total, ICP-MS	0.1725	0.1700	0.2100
Copper, Total, ICP-MS	1.0052	0.9880	1.0700
Lead, Total, ICP-MS	0.0659	0.0250	0.3350
Nickel, Total, ICP-MS	0.5038	0.4930	0.5710
Zinc, Total, ICP-MS	0.7609	0.7100	1.1000
Hardness, Calculated - (mg/L)	37.97	37.60	
Filtered Metals - Values in ug/L			
Mercury, Dissolved, CVAF	0.000261	0.000250	0.000350
Cadmium, Dissolved, ICP-MS	0.0050	0.0100	N/A
Chromium, Dissolved, ICP-MS	0.1316	0.1300	0.1650
Copper, Dissolved, ICP-MS	0.8903	0.8695	0.9470
Lead, Dissolved, ICP-MS	0.0125	0.0250	N/A
Nickel, Dissolved, ICP-MS	0.4705	0.4675	0.5070
Zinc, Dissolved, ICP-MS	0.7022	0.7000	0.8180

Notes:

Data provided by METRO/King County Department of Natural Resources Water and Land Resources Division. Data used in this analysis is from DNR-Lake Washington sampling stations 0826, 0850, and 0890.

[1] <MDL - all values less than Method Detection Limit-value reported is 1/2 the MDL
[2] Data set includes values reported as less than the MDL. Calculation used 1/2 the MDL for those values.
[3] Data set includes values with a B qualifier indicating Blank contamination for that analyte.

Table H-2
Filtered Metals: Lake Washington Surface Samples Collected Autumn 2000

PROJECT: 423478		Locator 0826				Locator 0852				Locator 0890			
		(LAKE WASHINGTON//M)[a]				(Madison Park)[b]				(Lake Washington)[c]			
Parameters		Value (mg/L)	Qual	MDL (mg/L)	RDL (mg/L)	Value (mg/L)	Qual	MDL (mg/L)	RDL (mg/L)	Value (mg/L)	Qual	MDL (mg/L)	RDL (mg/L)
Mercury, Dissolved, CVAF	EPA 1631	2.2E-07	<RDL	1E-07	5E-07	2E-07	<RDL	1E-07	5E-07	1.6E-07	<RDL	1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.8	0.00013	<RDL,B	0.00005	0.00025	0.00018	<RDL	0.00005	0.00025	0.00012	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.8	0.00091		0.0001	0.0005	0.00089		0.0001	0.0005	0.00085		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.8		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.8	0.00047		0.00005	0.00025	0.00046		0.00005	0.00025	0.00043		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.8	0.00072	<RDL,B	0.00015	0.00075	0.00057	<RDL,B	0.00015	0.00075	0.0005	<RDL,B	0.00015	0.00075

[a] Sampled: Sep 20, 2000
Lab ID: L18728-11
Matrix: Filter water
Sample depth: 1 meter below water surface

[b] Sampled: Sep 21, 2000
Lab ID: L18729-1
Matrix: Filter water
Sample depth: 1 meter below water surface

[c] Sampled: Sep 21, 2000
Lab ID: L18729-19
Matrix: Filter water
Sample depth: 1 meter below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-3
Filtered Metals: Lake Washington Mid-Depth Samples Collected Autumn 2000

PROJECT: 423478		Locator 0826				Locator 0852				Locator 0890			
		(LAKE WASHINGTON//M)[a]				(Madison Park)[b]				(Lake Washington)[c]			
Parameters		**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**
Mercury, Dissolved, CVAF	EPA 1631	4.8E-07	<RDL	1E-07	5E-07	6.4E-07		1E-07	5E-07	6E-07		1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.8	0.00012	<RDL	0.00005	0.00025	0.00017	<RDL	0.00005	0.00025	0.00023	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.8	0.00095		0.0001	0.0005	0.00098		0.0001	0.0005	0.00103		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.8	5.1E-05	<RDL	0.000025	0.000125	0.00011	<RDL	0.000025	0.000125	0.00014		0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.8	0.00049		0.00005	0.00025	0.00049		0.00005	0.00025	0.00051		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.8	0.00071	<RDL	0.00015	0.00075	0.00088		0.00015	0.00075	0.00093		0.00015	0.00075

[a] Sampled: Sep 20, 2000
Lab ID: L18728-12
Matrix: Filter water
Sample depth: 47 meters below water surface

[b] Sampled: Sep 21, 2000
Lab ID: L18729-2
Matrix: Filter water
Sample depth: 62 metesr below water surface

[c] Sampled: Sep 21, 2000
Lab ID: L18729-20
Matrix: Filter water
Sample depth: 53 meters below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-4
Filtered Metals: Lake Washington Surface Samples Collected Winter 2000/2001

PROJECT: 423478		Locator 0826				Locator 0852				Locator 0890			
		(LAKE WASHINGTON//M)[a]				(Madison Park)[b]				(Lake Washington)[c]			
Parameters		**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**
		- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis			
Mercury, Dissolved, CVAF	EPA 1631	3.4E-07	<RDL	1E-07	5E-07	2.6E-07	<RDL	1E-07	5E-07	1.8E-07	<RDL	1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.8	0.00015	<RDL	0.00005	0.00025	0.00011	<RDL,B	0.00005	0.00025	0.00011	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.8	0.00087		0.0001	0.0005	0.00095	B	0.0001	0.0005	0.00104		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.8		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.8	0.00051		0.00005	0.00025	0.00049		0.00005	0.00025	0.00046		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.8	0.0007	<RDL	0.00015	0.00075	0.00061	<RDL,B	0.00015	0.00075	0.00082	B	0.00015	0.00075

[a] Sampled: Dec 12, 2000
Lab ID: L22780-11
Matrix: Filter water
Sample depth: 1 meter below water surface

[b] Sampled: Jan 31, 2001
Lab ID: L19685-1
Matrix: Filter water
Sample depth: 1 meter below water surface

[c] Sampled: Jan 29, 2001
Lab ID: L19685-19
Matrix: Filter water
Sample depth: 1 meter below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-5
Filtered Metals: Lake Washington Mid-Depth Samples Collected Winter 2000/2001

PROJECT: 423478		**Locator 0826**				**Locator 0852**				**Locator 0890**			
		(LAKE WASHINGTON//M)[a]				**(Madison Park)**[b]				**(Lake Washington)**[c]			
Parameters		**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**
		- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis			
Mercury, Dissolved, CVAF	EPA 1631	3.2E-07	<RDL	1E-07	5E-07	2.4E-07	<RDL	1E-07	5E-07	1.9E-07	<RDL	1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.8	0.00015	<RDL	0.00005	0.00025	9.9E-05	<RDL,B	0.00005	0.00025	0.00011	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.8	0.00088		0.0001	0.0005	0.00086	B	0.0001	0.0005	0.00087		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.8		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.8	0.00052		0.00005	0.00025	0.00048		0.00005	0.00025	0.00045		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.8	0.0007	<RDL	0.00015	0.00075	0.00071	<RDL,B	0.00015	0.00075	0.00064	<RDL,B	0.00015	0.00075

[a] Sampled: Dec 12, 2000
Lab ID: L22780-12
Matrix: Filter water
Sample depth: 47 meters below water surface

[b] Sampled: Jan 31, 2001
Lab ID: L19685-2
Matrix: Filter water
Sample depth: 62 meters below water surface

[c] Sampled: Jan 29, 2001
Lab ID: L19685-20
Matrix: Filter water
Sample depth: 47 meters below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-6
Total Metals: Lake Washington Surface Samples Collected Autumn 2000

PROJECT: 423478		**Locator 0826**				**Locator 0852**				**Locator 0890**			
		(LAKE WASHINGTON//M)[a]				**(Madison Park)[b]**				**(Lake Washington)[c]**			
Parameters		**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**
Mercury, Dissolved, CVAF	EPA 1631	3.6E-07	<RDL	1E-07	5E-07	3.3E-07	<RDL	1E-07	5E-07	2.4E-07	<RDL	1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.9	0.00012	<RDL	0.00005	0.00025	0.00015	<RDL	0.00005	0.00025	0.00017	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.10	0.00107		0.0001	0.0005	0.00098		0.0001	0.0005	0.00102		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.11		<MDL	0.000025	0.000125		<MDL	0.000025	0.000125	2.7E-05	<RDL	0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.12	0.00047		0.00005	0.00025	0.00046		0.00005	0.00025	0.00047		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.13	0.0006	<RDL	0.00015	0.00075	0.00041	<RDL	0.00015	0.00075	0.00071	<RDL	0.00015	0.00075
Hardness, Calc (units = mg CaCO3/L)	SM2340 B.ED19	37.6		0.2	1.25	37.6		0.2	1.25	37.6		0.2	1.25

[a] Sampled: Sep 20, 2000
Lab ID: L18728-12
Matrix: Fresh water
Sample depth: 47 meters below water surface

[b] Sampled: Sep 21, 2000
Lab ID: L18729-2
Matrix: Fresh water
Sample depth: 62 metesr below water surface

c Sampled: Sep 21, 2000
Lab ID: L18729-20
Matrix: Fresh water
Sample depth: 53 meters below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-7
Total Metals: Lake Washington Mid-Depth Samples Collected Autumn 2000

PROJECT: 423478		Locator 0826				Locator 0852				Locator 0890			
		(LAKE WASHINGTON//M)[a]				(Madison Park)[b]				(Lake Washington)[c]			
Parameters		**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**
Mercury, Dissolved, CVAF	EPA 1631	4.8E-07	<RDL	1E-07	5E-07	6.4E-07		1E-07	5E-07	6E-07		1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.9	0.00012	<RDL	0.00005	0.00025	0.00017	<RDL	0.00005	0.00025	0.00023	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.10	0.00095		0.0001	0.0005	0.00098		0.0001	0.0005	0.00103		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.11	5.1E-05	<RDL	0.000025	0.000125	0.00011	<RDL	0.000025	0.000125	0.00014		0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.12	0.00049		0.00005	0.00025	0.00049		0.00005	0.00025	0.00051		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.13	0.00071	<RDL	0.00015	0.00075	0.00088		0.00015	0.00075	0.00093		0.00015	0.00075
Hardness, Calc (units = mg CaCO3/L)	SM2340 B.ED19	36		0.2	1.25	37		0.2	1.25	37.3		0.2	1.25

[a] Sampled: Sep 20, 2000
Lab ID: L18728-12
Matrix: Fresh water
Sample depth: 1 meter below water surface

[b] Sampled: Sep 21, 2000
Lab ID: L18729-1
Matrix: Fresh water
Sample depth: 1 meter below water surface

[c] Sampled: Sep 21, 2000
Lab ID: L18729-19
Matrix: Fresh water
Sample depth: 1 meter below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-8
Total Metals: Lake Washington Surface Samples Collected Winter 2000/2001

PROJECT: 423478		**Locator 0826**				**Locator 0852**				**Locator 0890**			
		(LAKE WASHINGTON//M)[a]				**(Madison Park)[b]**				**(Lake Washington)[c]**			
Parameters		**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**	**Value (mg/L)**	**Qual**	**MDL (mg/L)**	**RDL (mg/L)**
		- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis			
Mercury, Dissolved, CVAF	EPA 1631	4.5E-07	<RDL	1E-07	5E-07	3.5E-07	<RDL	1E-07	5E-07	3.6E-07	<RDL	1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.8	0.00019	<RDL	0.00005	0.00025	0.00018	<RDL	0.00005	0.00025	0.00017	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.8	0.00097		0.0001	0.0005	0.00115		0.0001	0.0005	0.00098		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.8	6.5E-05	<RDL	0.000025	0.000125	7.4E-05	<RDL	0.000025	0.000125	5.4E-05	<RDL	0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.8	0.00057		0.00005	0.00025	0.00051		0.00005	0.00025	0.00049		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.8	0.0011		0.00015	0.00075	0.0007	<RDL	0.00015	0.00075	0.00057	<RDL	0.00015	0.00075
Hardness, Calc (units = mg CaCO3/L)	SM2340 B.ED19	40.9		0.2	1.25	38.2		0.2	1.25	37.1		0.2	1.25

[a] Sampled: Dec 12, 2000
Lab ID: L22780-11
Matrix: Fresh water
Sample depth: 1 meter below water surface

[b] Sampled: Jan 31, 2001
Lab ID: L19685-1
Matrix: Fresh water
Sample depth: 1 meter below water surface

[c] Sampled: Jan 29, 2001
Lab ID: L19685-19
Matrix: Fresh water
Sample depth: 1 meter below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter

Table H-9
Total Metals: Lake Washington Mid-Depth Samples Collected Winter 2000/2001

PROJECT: 423478		Locator 0826				Locator 0852				Locator 0890			
		(LAKE WASHINGTON//M)[a]				(Madison Park)[b]				(Lake Washington)[c]			
Parameters		Value (mg/L)	Qual	MDL (mg/L)	RDL (mg/L)	Value (mg/L)	Qual	MDL (mg/L)	RDL (mg/L)	Value (mg/L)	Qual	MDL (mg/L)	RDL (mg/L)
		- Wet Weight Basis				- Wet Weight Basis				- Wet Weight Basis			
Mercury, Dissolved, CVAF	EPA 1631	4.7E-07	<RDL	1E-07	5E-07	4.3E-07	<RDL	1E-07	5E-07	4.2E-07	<RDL	1E-07	5E-07
Cadmium, Dissolved, ICP-MS	EPA 200.8		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005		<MDL	0.00001	0.00005
Chromium, Dissolved, ICP-MS	EPA 200.8	0.00021	<RDL	0.00005	0.00025	0.0002	<RDL	0.00005	0.00025	0.00016	<RDL	0.00005	0.00025
Copper, Dissolved, ICP-MS	EPA 200.8	0.00101		0.0001	0.0005	0.001		0.0001	0.0005	0.00092		0.0001	0.0005
Lead, Dissolved, ICP-MS	EPA 200.8	7.4E-05	<RDL	0.000025	0.000125	0.00011	<RDL	0.000025	0.000125	6.4E-05	<RDL	0.000025	0.000125
Nickel, Dissolved, ICP-MS	EPA 200.8	0.00057		0.00005	0.00025	0.00052		0.00005	0.00025	0.00049		0.00005	0.00025
Zinc, Dissolved, ICP-MS	EPA 200.8	0.00116		0.00015	0.00075	0.00076		0.00015	0.00075	0.00061	<RDL	0.00015	0.00075
Hardness, Calc (units = mg CaCO3/L)	SM2340 B.ED19	40.6		0.2	1.25	37.4		0.2	1.25	38.3		0.2	1.25

[a] Sampled: Dec 12, 2000
Lab ID: L22780-12
Matrix: Fresh water
Sample depth: 47 meters below water surface

[b] Sampled: Jan 31, 2001
Lab ID: L19685-2
Matrix: Fresh water
Sample depth: 62 meters below water surface

[c] Sampled: Jan 29, 2001
Lab ID: L19685-20
Matrix: Fresh water
Sample depth: 47 meters below water surface

Abbreviations
MDL = Method detection limit
RDL = Regulatory detection limit
B =
mg/L = milligrams per liter